NASA SP-5002

TECHNOLOGY UTILIZATION

SOLDERING ELECTRICAL CONNECTIONS

A HANDBOOK

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

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A HANDBOOK

Fourth Edition

Technology Utilization Division
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Foreword

The National Aeronautics and Space Administration published the third edition of *Reliable Electrical Connections* (SP–5002) in 1964. The handbook had been prepared and used as an internal document at the George C. Marshall Space Flight Center in the course of that center's efforts to increase the dependability of soldered electrical connections. As a result of publication by NASA Headquarters and wider distribution, many thousands of readers both inside and outside NASA found SP–5002 so helpful that there have been five printings of it since 1964. For this fourth edition, the authors have again revised the text, adding to many sections.

This is but one of many publications issued by the Office of Technology Utilization to make technical information acquired by NASA and its contractors widely available. All of these publications are addressed to those who can benefit from the experience acquired in the Nation's space program.

GEORGE J. HOWICK,
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Introduction

A space vehicle is no more dependable than its components. Because most functional components of space vehicle systems are electrical or electromechanical, it is imperative to obtain the greatest possible dependability in electrical connections within those components. Connections acceptable in commercial electrical or electronic equipment cannot be relied on to withstand the vibration and G-loads imposed by space flights.

NASA has developed more rigorous standards and specifications than those in general use by industry for commercial and industrial equipment. Such standards and specifications must be used for design, manufacture, and acceptance of space vehicle components. These standards stress techniques, proper tools, correct materials, workmanship, and 100 percent inspection in all areas: receiving, in-process, and final.

Design can affect workmanship and reliability. Poor design, such as too many wires in a solder cup or terminal, may force compromises which conflict with the requirements of the specifications. It is imperative, therefore, that designers take specifications into consideration to preclude the possibility of compromises which could affect component reliability.

Standards and specifications are futile unless the assembler has been trained in the proper techniques and the inspector has been trained to recognize unacceptable work. Good workmanship and quality control are the key to dependability.

To achieve good workmanship, training sessions should be established in the plant to instruct personnel in the use of proper techniques, tools, materials, and standards. During this training it will be necessary for the students to adapt themselves to the new standards and requirements, and to refrain from using previously common practices that are not acceptable for space vehicles.

Personnel training should also include shop foremen and supervisors to enable them to differentiate between proper and improper work. Satisfactory supervisory training results in the detection of most improper work prior to inspection, thus reducing time spent and expense incurred in rework.

Specifications and worker training are not enough, however. Inspections must also be performed. Inspection personnel need training similar to that given to the assemblers. Inspection personnel, when trained and experienced in performing acceptable work, become proficient in recognizing acceptable or unacceptable work performed by others.

After successful completion of the training course, the proficiency of each individual assembler and inspector must be constantly reviewed and evaluated. Persons who become deficient should be returned to training sessions for refresher courses and/or learning new techniques.

One hundred percent receiving and in-process inspection has proven to be worth the extra expense and effort; it prevents imperfect parts from being installed, or unacceptable work being covered by subsequent operations. Rejectable work is discovered in time to prevent unnecessary rework or scrap.

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SECTION 1

Hand Soldering

TOOLS

Good work may be turned out occasionally with poor tools, but this is an exception. Using the wrong tool invariably requires more time, and the attempt increases the possibility of poor quality. The correct tool, properly used and maintained in good working condition, results in quality workmanship and contributes to the skill and the pride of the workman in a job well done.

The following tools (fig. 1) are necessary individual tools and should be assigned to or owned by the operator.

- Round-nose bending pliers
- Long-nose pliers
- Diagonal cutting pliers
- Tweezers (including self-locking type)
- Soldering aid
- File (for dressing soldering irons)
- Scissors (small, thin blade)

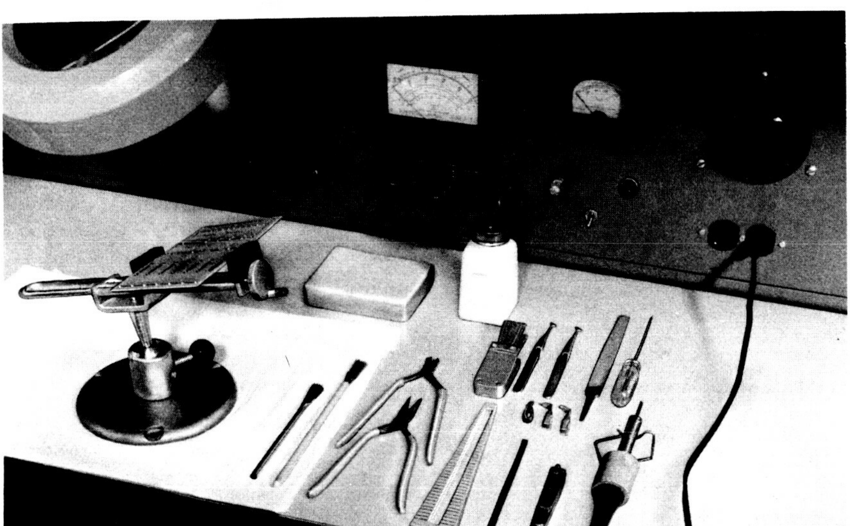

FIGURE 1. Soldering tools.

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The following tools are also necessary, but are usually issued as the job requires:

- Calibrated precision cutting-type wire strippers
- Thermal wire-stripping apparatus
- Variable voltage control transformer
- Soldering iron and spare tips
- Heat dissipator clamps (thermal shunts)
- Printed wiring board holding fixtures
- Tensioning spring
- Magnifying bench lamp (for miniature work)
- Resistance soldering apparatus
- Sponge (for cleaning soldering iron tip)

The following are expendable supplies, issued for specific job requirements:

- Lacing cord or plastic ties
- Core solder (Sn60 or Sn63)
- Liquid flux
- Alcohol or other approved cleaning fluid
- Bristle brushes
- Clear flexible tubing

The following special equipment, when available, is used in preparation and soldering:

- Automatic wire strippers and cutters
- Lead bending and cutting machines
- Automatic part insertion machines
- Automatic soldering machines
- Ultrasonic solder pots and ultrasonic cleaning equipment

WORK AREA

Sufficient light, properly directed, is a prime requirement for quality work. This may be provided by a combination of glare-free area lighting and adjustable supplementary light sources at the work surface. A light level of 100 footcandles at the work piece is considered necessary for adequate visibility to assemble miniature parts and connectors.

A neat and orderly work area contributes to quality work by reducing confusion. Tools should be arranged within easy reach, and each tool should be kept in a specified place. Plastic trays or shallow pans lined with industrial towels have been successfully used for holding tools. Only those tools required for the current series of operations should be at the operator's position.

Misplaced or inaccessible tools cause delays and tempt the workman to use the wrong tool. This can lead to rejections, reworks, delays, and degradation of the end product.

SAFETY

The safety of a work area depends on the development and maintenance of safety practices by all personnel in the area. A general list of these practices appears below; other practices, for special areas, should also be developed and maintained.

1. Place the soldering iron in a location that will not require reaching across or around it. Place the soldering iron in the upper corner of the work area when not in use.

2. When unsoldering a wire, make certain that there is no tension or spring to the wire. Safety glasses should be worn during this operation to shield eyes from hot solder.

3. Plug soldering iron into proper electrical socket and keep plug free from strands of wire or metal.

4. When cutting wires, keep the open side of the cutter away from the body, keep the wire pieces in the work area, and keep wire pieces from other work areas from entering your area.

5. Disconnect all electrical power before working on a chassis.

6. Insure that blade-type screwdriver bits are square and sharp, and use screwdrivers only for the work for which they were designed.

7. Connect the airhose to the air supply nearest to the work area; keep the hose out of the aisle, and keep excess hose reeled in.

8. When cleaning with an air hose, use a pressure-controlled nozzle with minimum pressure, insure that the air stream is not directed toward personnel, and wear safety glasses. Do not clean clothes with air pressure.

9. When working with solvents, keep a minimum amount of solvent in a safety can. DO NOT SMOKE, and do not spill solvent over the work area.

10. Safety glasses should be worn when work such as cutting wires, soldering, or using solvent is performed overhead.

11. Women working in the solder area should wear low-heeled shoes with closed toes and heels. Other recommended apparel includes hair nets and slacks or coveralls. Loose clothing is dangerous around moving machinery.

PREPARING CONDUCTORS AND PART LEADS

Insulation Stripping

To strip insulation, nonadjustable, factory set, cutting-type strippers should be used. Figure 2 shows a typical hand stripping tool.

When using tools with multiple stripping holes, the correct hole for the gage of wire being stripped must be used. Tools equipped with

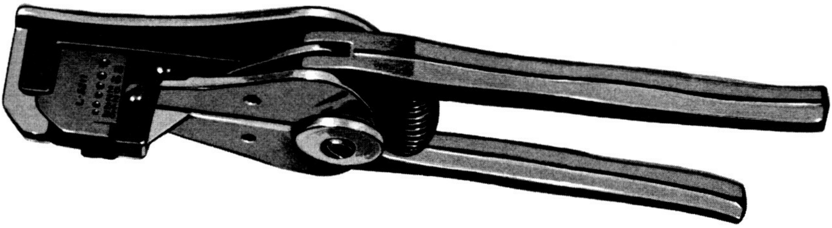

FIGURE 2. Proper cutting-type stripper.

single dies are recommended. For long production runs on single wire sizes, the unused holes in multiple wire strippers may be masked off to prevent accidental use of an undersized hole which could result in nicks, cuts, and scrapes to the wire strands. The calibration of all precision-type cutting strippers should be checked periodically. Out-of-tolerance strippers should be removed from the work area.

Thermal-type strippers (fig. 3) may be used on certain types of wire insulation which can be effectively stripped by this method. Care should be taken to eliminate burned insulation residue which would impair solderability. Ventilation should be provided where thermal strippers are used. Inhalation of the vapors from the breakdown of polymerized organic insulations can cause polymer fume fever.

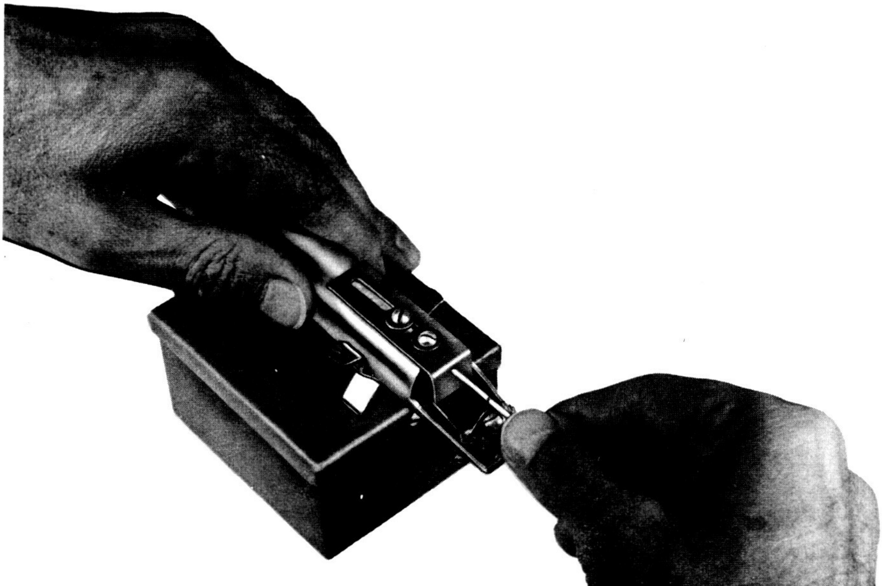

FIGURE 3. Thermal stripper.

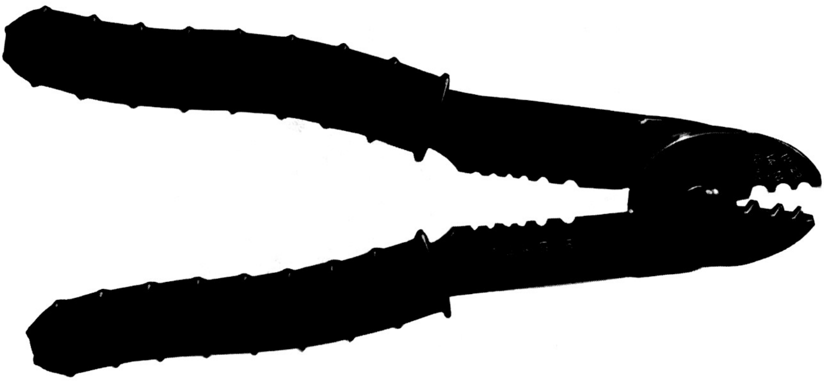

FIGURE 4. Improper cutting-type stripper.

If the stripping operation has caused the strands to become separated or disarranged, the strands should be restored to the original lay before the ends are tinned.

Stripped wire with nicked or cut strands is not acceptable, *because* the stress concentration will cause failure during vibration. For this reason, cutting-type strippers of the type shown in figure 4 must not be used under any circumstances. They will invariably cut, nick, or scrape strands of wire.

Insulation Damage

Excessive pressure by the gripping jaws of hand-operated strippers will crush the insulation at the wire end. Incorrect gripping blocks in the machine-type stripper will also damage the insulation. Wire with damaged insulation should not be used. Slight discoloration as a result of thermal stripping is acceptable.

Insulation Gap

The end of the insulation should be far enough from the soldered joint that the insulation cannot become embedded in the solder, yet not so far as to permit a short circuit between two adjacent wires. In general, the length of the gap should be a distance equal to approximately a wire diameter (fig. 5).

Cleaning Part Lead

To assure a good wetting action between parts to be soldered, all impurities such as dirt, grease, or oxide film, must be removed. Surface contamination or corrosion formed on the part lead during processing,

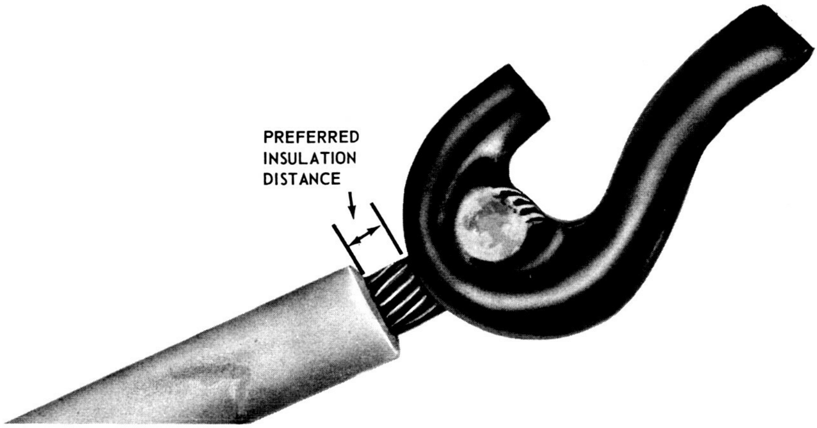

FIGURE 5. Proper insulation gap.

storage, or handling should be removed. A typical cleaning tool is shown in figure 6. The lead should be retinned with an alloy of the same composition as will be used in the soldering operation.

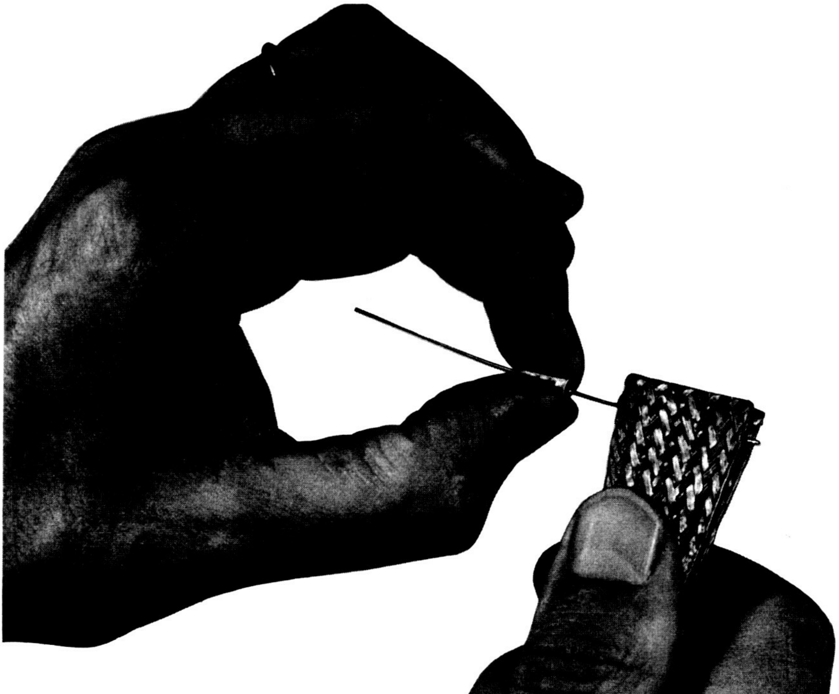

FIGURE 6. Typical cleaning tool.

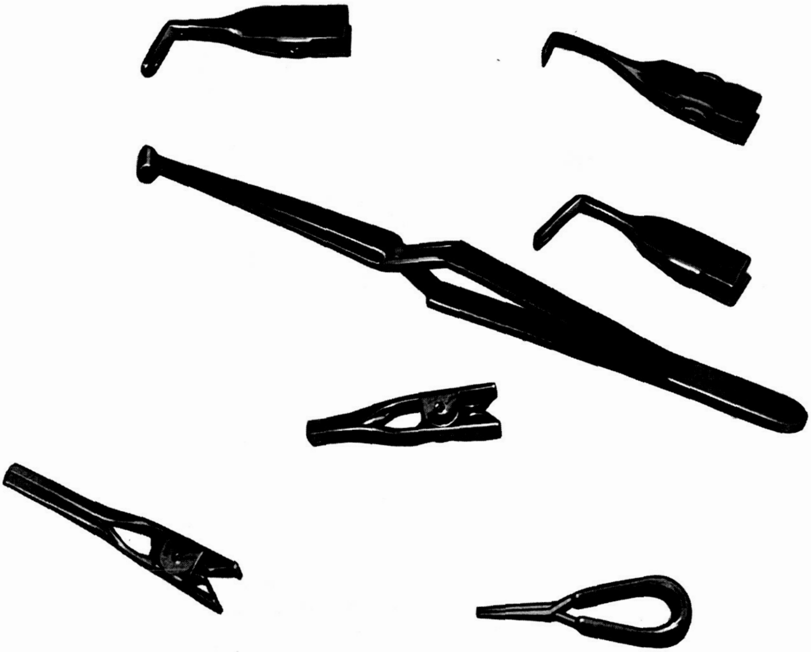

FIGURE 7. Typical heat sinks.

Heat Sinks

Heat sinks (also called thermal shunts or heat dissipator clamps) should be used to absorb heat from part leads to protect heat sensitive parts or previously completed connections from damage during the soldering operation (fig. 7). Care should be taken in applying and removing heat sinks to avoid damage to the finish or insulation.

Stress Relief

An allowance for expansion and contraction during temperature cycling should be made in all part leads. This applies not only to parts with axial leads, but also to solid jumper wires which could transmit tensile or compressive forces.

Vibration Bend

Wires connected to a terminal board or to a part having fixed terminals should have slack in the form of a gradual bend to allow flexing during vibration (fig. 8). When multiple wires are routed from a cable trunk to equally spaced terminals, a uniform amount of slack should

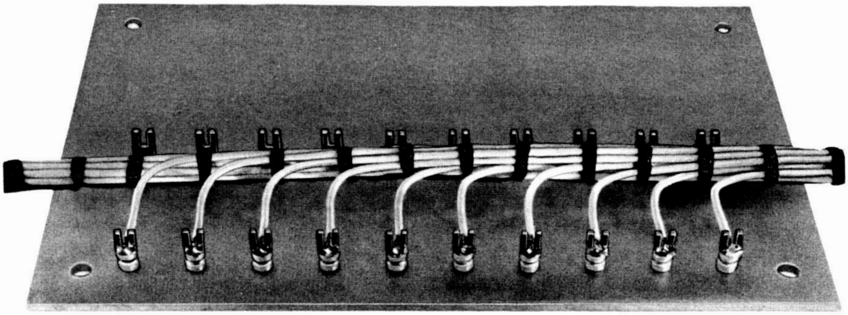

FIGURE 8. Typical vibration bends.

be provided to prevent concentration of stress in the shortest wire. The cable trunk should be clamped or supported to avoid stresses on the electrical connection.

Hermetically Sealed Parts

A brittle glass material is used to seal part leads or terminals on hermetically sealed parts (fig. 9). The glass seal is fragile; any flexing or bending of the lead or terminals will cause the glass to crack, thereby destroying the effectiveness of the seal. This is applicable to all seals made with brittle materials.

These parts should be visually examined prior to mounting to determine if the glass seals are damaged.

The soldering operator should not attempt to straighten or bend the terminals. This operation should be performed only by designated

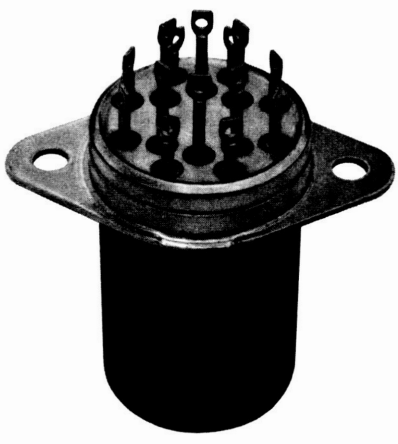

FIGURE 9. Hermetically sealed part.

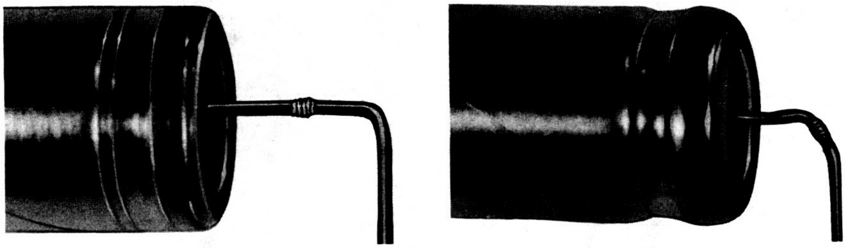

FIGURE 10. Proper lead bend (left), and improper lead bend (right).

skilled personnel with special equipment. The degradation from cracked seals is so gradual that immediate electrical tests will not detect it; suspected parts should be returned for leak tests.

When lacing a harness after the wires have been soldered to glass seal terminals, extreme care should be taken to avoid placing stress on the terminals.

Tantalum Capacitors

Extreme care should be exercised when bending welded leads of tantalum capacitors and other parts similarly constructed. The bend should be made beyond the weld rather than between the weld and the part body. See figure 10.

SOLDERING

Tin melts at 450° F.; lead melts at 621° F. Eutectic tin-lead solder melts at 361° F. Solders other than eutectic melt at higher temperatures. The chart in appendix A provides information on the melting points of the various tin-lead compositions.

When heat is applied to solder other than eutectic, it becomes plastic and then liquid. Upon removal of heat, the order is reversed, the solder changing from liquid to plastic and then to a solid state. If either member of a joint is moved in relation to the other while the solder is in the plastic state, the solder will become coarse grained, and the resulting connection will be physically weak and unreliable. Such a joint is called a fractured joint (fig. 11) and should be reworked.

The length of time that solder is kept molten and the temperature at which it is maintained while a liquid are critical since molten solder absorbs gases. If excessive temperature has been used or the solder has been molten too long, the molten alloy will oxidize, and the solder will appear granular and gray when cool. The solder connection will be physically weak and unreliable.

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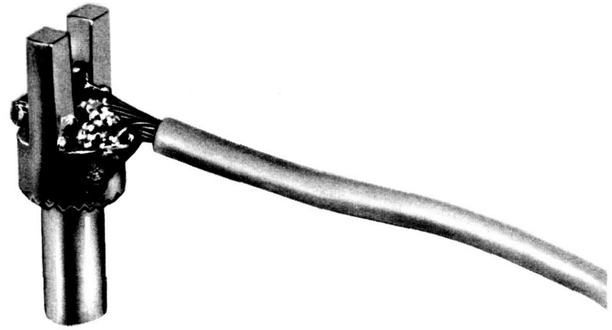

FIGURE 11. Fractured joint.

Solder and Flux

The core of wire solder should contain only rosin or activated rosin fluxes. For general use, solder composition Sn60 or Sn63 (60 or 63 percent tin and 40 or 37 percent lead) should be used. On miniature printed circuits and in other applications where the heat should be minimized, eutectic solder (Sn63) should be used. Other compositions should be used only when specified.

Soldering paste, acid-type fluxes, or other corrosive on conducting-type fluxes should not be used.

In some applications, such as removing excess solder by wicking into a stranded wire or piece of shielding braid, tinning for nickel-plated wire, or for solder-pot tinning of wire, liquid-rosin flux may be used. To prevent undesirable chemical reaction, the activating material in the liquid-rosin flux must be compatible with the core flux of the wire solder used in the assembly.

Flux Application

Flux should be applied to a surface before the solder melting temperature is reached. The rosin in core solder melts before the solder and the application occurs automatically.

If excessive temperatures are used, rosin flux will carbonize, and will hinder soldering rather than aid it.

Tinning Stranded Wire

Tinning of the wire should extend only far enough to take full advantage of the depth of the terminal or solder cup. The ends of the stranded wires should be stripped and dipped in liquid flux to the depth that tinning is desired. Tinning is then accomplished by either dipping the wire into a solder pot with a controlled temperature of 500° ±20° F. (fig. 12) or by using a soldering iron and cored solder (fig. 13).

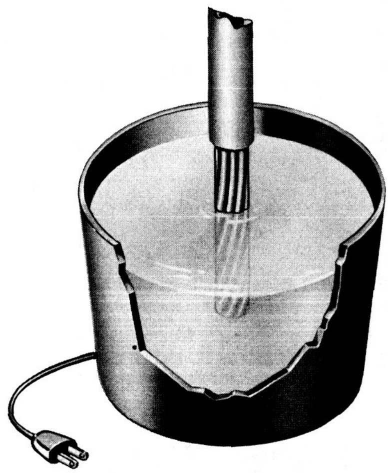

FIGURE 12. Typical solder pot.

If it becomes necessary to strip and tin or solder wires within an assembly, care should be taken to avoid dripping or spraying solder or dropping insulation residue and other impurities.

Holding

Materials being soldered should be held motionless with respect to each other. Depending on the type of termination, the tinned end of the wire should be formed into a hook or loop, held firmly against the joining member during soldering, cooling, and solidification.

Devices such as those shown in figure 14 are satisfactory to hold a wire motionless. Other holding devices will perform equally well.

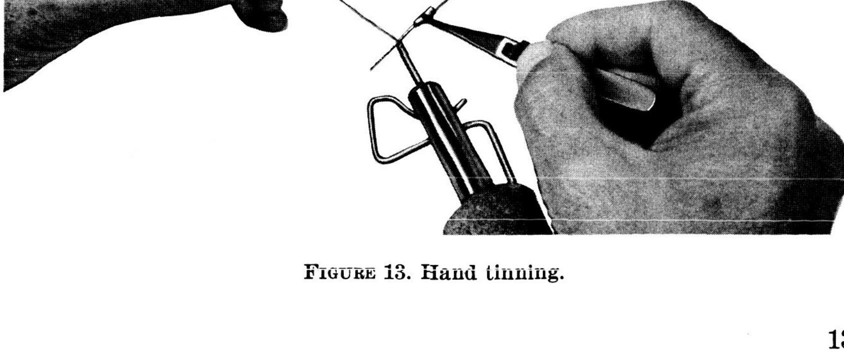

FIGURE 13. Hand tinning.

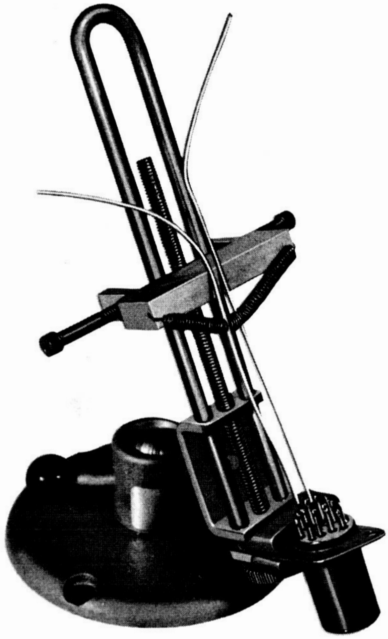

FIGURE 14. Holding devices.

Soldering Irons

Research has shown that the best solder joints are produced within a narrow range of temperature and application time. Joint temperatures of 500 to 550° F., applied for 1 to 2 seconds, result in the strongest connections. Size, wattage, and shape of the iron should be selected to approach these conditions as closely as possible. When the tip is applied, it should rapidly heat the joint to soldering temperature. The amount of heat capacity in the tip implies that the mass of the tip is large with respect to the mass of the metal being heated for solder application.

The tip must not be so large as to obscure visibility of the workpiece, or to cause damage to adjacent parts or wire insulation. The tip shape, such as spade, chisel, or pyramid, should be appropriate for the workpiece. It is good practice to keep an assortment of spare tips and to change the tip as necessary to meet the requirements of various types of work.

A variable voltage supply is recommended for controlling the soldering iron temperature when soldering printed circuits; it is also advantageous in many other soldering applications. By proper selection of tips and correct voltage adjustment, a single 50-watt pencil-type iron can be used for soldering miniature printed circuits or relatively large terminals. Thermostatically controlled irons require less skill in the judgment of heat but are somewhat less versatile.

The unplated copper tip will produce the best results, and therefore is recommended. This does not exclude the use of plated tips for production work, provided the quality of the solder connections can be maintained.

Copper tips in an unheated condition should be dressed smooth with a suitable file. After the tip has been filed and the minimum temperature required to melt solder has been reached, apply solder to the dressed face of the tip. Clean the tip by wiping on a wet sponge or other suitable material before each connection is made.

NOTE

Do not change from unplated tips to plated tips during a single operation without allowing for the extra time required for heat transfer from the plated tip.

Heat Application With Soldering Iron

The soldering iron tip should be applied to the metal part having the greatest mass (fig. 15). Ordinarily, in a wire-to-terminal connection, the greatest mass is the terminal. Fresh tinning on the tip of the iron provides quick transfer of heat to the workpiece.

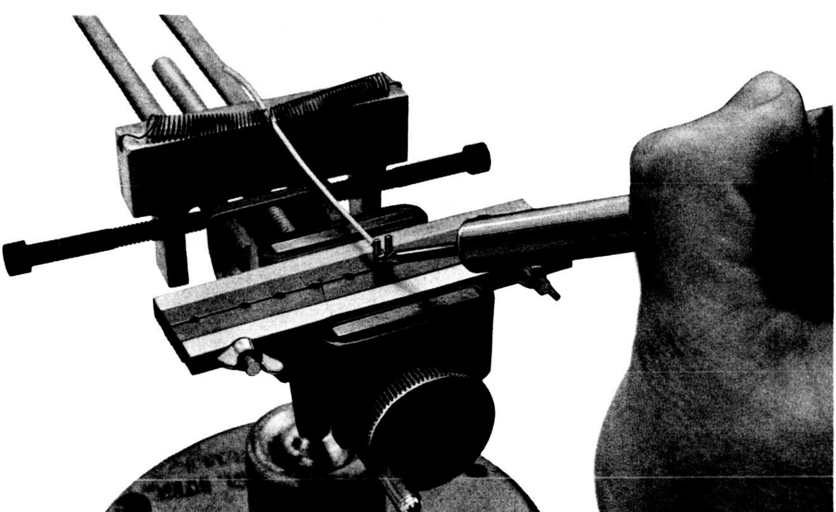

FIGURE 15. Proper application of heat.

Solder should be applied to the junction of the joint members (not to the soldering iron) as soon as they will readily melt the solder. The iron should be tilted sufficiently to allow the solder to be applied to the junction. The iron should be withdrawn as soon as the joint is complete to avoid overheating the molten solder.

The surface temperature of both metals being soldered must be above the solder melting point to expedite efficient wetting. Solder should not be permitted to flow onto a surface cooler than the solder temperature; this will cause cold or "rosin" joints.

Solder applied to a properly cleaned, fluxed, and heated surface will melt and flow without direct contact with the heat source. It will have a smooth, even surface, feathering out to a thin edge. A built-up, irregular appearance is an indication of improper solder application.

A good solder joint has the following characteristics: A smooth surface, even distribution of solder to a feather edge at the base metal, no porosity, good fillet between conductors, and good adherence to both parts. Charred or carbonized flux residue indicates excessive application of heat. Solder obscuring the contour of the wire, and making visual inspection difficult or impossible, is classified as excess solder.

Resistance Soldering

Resistance soldering (fig. 16) is an effective method of supplying heat to the metal to be soldered. This process passes current through the metal to be soldered. The heat generated at the interface of the metal and the electrode is used to melt the solder. The proper mating pin or socket should be used to avert damaging the connector.

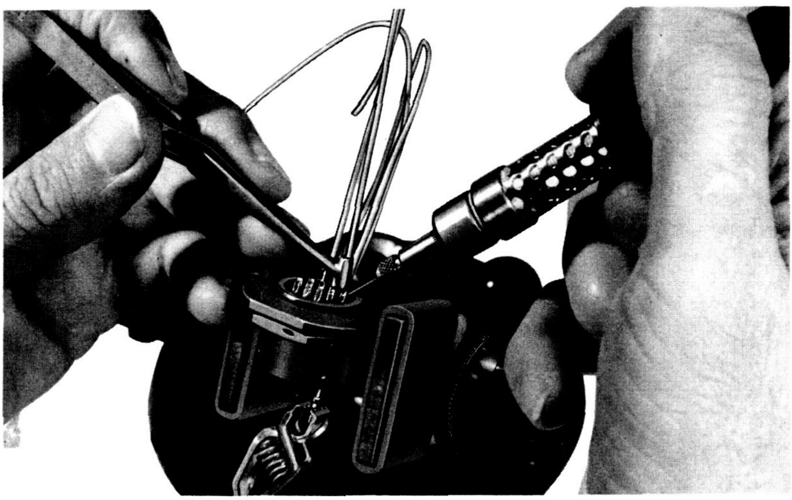

FIGURE 16. Typical resistance soldering.

Since resistance soldering generates heat directly in the metal area to be soldered, it offers the advantage of localizing or confining the heat to a selected area. This method is well adapted to the soldering of connectors.

In one application of this method, tweezer-type electrodes are used; when the metal is gripped between the electrodes, an electric circuit is completed through a low-voltage transformer and the metal between the electrodes is heated.

Another application uses a carbon pencil; the return circuit is a metalic connection. When contact is made by the carbon pencil, the metal of the terminal is heated at the point of contact (where the resistance is maximum).

> **NOTE**
>
> Place carbon tip or tweezer on terminal before pressing foot switch. Release switch before removing tip. This will prevent arcing and consequent damage to the plating.

Soldering Guns

Soldering guns are not to be used under any circumstances, because their temperatures are not controlled.

Cleaning Soldered Joints

Flux residue is often "tacky" and tends to collect dust and other foreign matter which could cause electrical leakage paths across insulator surfaces. To prevent this, the flux should be removed. After the solder has solidified, the flux residue should be dissolved with an approved solvent, applied with a bristle brush or sprayed, and the dissolved residues removed with industrial wiping tissues or other absorbent material. A clean part of the tissue should be used each time to avoid the possibility of transferring the dissolved flux back to the work.

> **CAUTION**
>
> Do not use large quantities of solvent, or attempt dipping in solvent, when switches, variable resistors, nonhermetically sealed relays, or any other nonsealed parts containing movable contacts are part of the assembly. The rosin dissolved in the cleaning solvent can enter spaces from which it cannot be removed and cause malfunction of the device.

Inspection of Completed Soldered Connections

The quality of a soldered connection can be determined by visual inspection. On miniaturized assemblies, it is necessary to use magnification. Wires should not be pulled or bent, nor force exerted on the connection with a soldering aid or other tool to test the mechanical soundness of the connection. Since the wire or part lead should not be bent or forced, it is necessary to inspect in steps when later assembly will make the solder joint impossible to inspect. If a joint must be reworked, it should be disassembled, the excess solder removed, and the area cleaned before reassembling in the same manner as a new joint.

Unsoldering

To remove wire from cup terminals, as in plugs or receptacles, the use of a resistance-type tool is the preferred method. A conduction-type soldering iron can be used. The tinned tip should be placed against the lower side of the cup. With either method, heat is transferred to the cup until the solder has melted. A light, steady pull should remove the wire. The excess solder remaining in the cup may then be removed by either wicking into a stranded wire or by using a vacuum type solder remover. Avoid prolonged heating of the terminal.

The soldering iron, with a tip well wetted with solder, should be used for unsoldering turret, split, pierced, or hook terminals. In close quarters it may be desirable to wick or vacuum most of the solder from the joint before attempting to disengage the wire from the terminal. Where splashing of solder is not critical, the connections may be melted, the wires lifted off gently, and the excess solder then removed by wicking or vacuuming.

CAUTION

Do not use the vacuum solder removal method on printed wiring boards, lest damage be done to the components to be soldered.

Joints which have been resoldered must meet the same criteria specified for the initial joints.

TERMINAL CONNECTIONS

Design is responsible for insuring that the size and number of terminals are sufficient to accommodate the conductors of an assembly. Terminal slots and solder cups should not be modified to accept oversize conductors, and conductors should not be modified to accommodate undersize terminals. Wires should not be spliced to other wires that enter the termination.

Hook Terminal Connections

The stripped and tinned wire should be bent a minimum of 90° and held against the terminal by tension during soldering. The end of the wire should extend no farther than a distance equal to one conductor diameter beyond the hook. A bend of approximately 180° (U shape) is also permissible (figs. 5 and 17). No attempt should be made to squeeze the tinned wire end against the hook with pliers (because the components to be soldered might be damaged).

Pierced Terminal Connections

A wire to be soldered to a pierced terminal should have a 90° minimum bend and should extend no farther than a distance equal to one conductor diameter beyond the terminal. The 180° bend is preferred. Both hook and pierced terminations should be protected by transparent flexible tubing (fig. 18). The tubing should be cut to length,

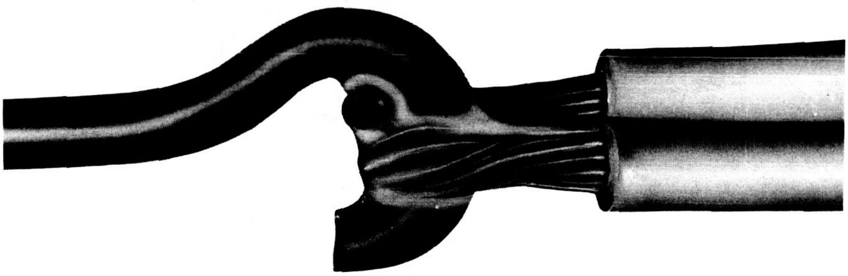

FIGURE 17. Hook terminal connection.

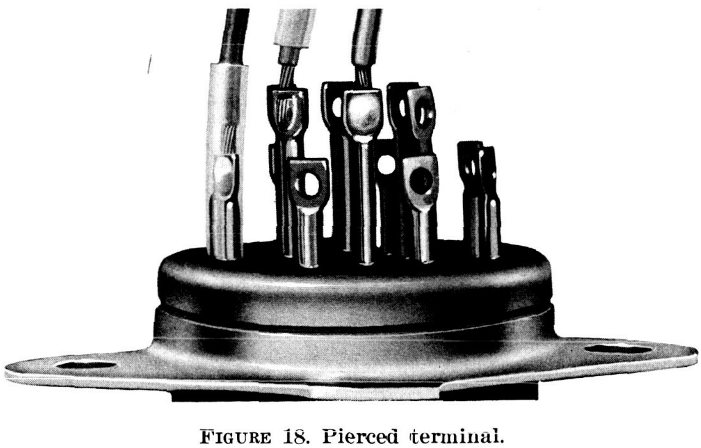

FIGURE 18. Pierced terminal.

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pushed up the wire before soldering, and slipped into position over soldered connection after the joint is cleaned and inspected. When in the final installed position, the tubing should overlap the wire insulation by a distance equal to at least a diameter.

Solder Cups (Connector Type)

Solder Cup Termination. The connection should be firmly mounted with the open end of the cups facing the operator. The wires should be soldered in rows, progressing from the bottom to the top. The cups may be prefilled before any of the wires are inserted. The cups should be heated, either with a resistance type tool or by holding the flat side of a soldering iron against the lower side of the cup, until the solder is completely melted. Keep the heat on the terminal until all trapped flux comes to the surface. The tinned wire should be slowly inserted into the molten solder until the wire bottoms in the cup. The conductor should be in contact with the back wall of the cup.

A smooth fillet should be formed between the conductor and the inner wall of the cup (fig. 19). The solder should follow the contour of the cup entry slot and should not spill over (exceed diameter of the cup as in fig. 20) or adhere to the outside of the cup (except for the slight tinned effect where the soldering iron tip contacts the side of the cup). Wicking of solder up to the point of insulation termination is permitted. All outside strands should be clearly discernible adjacent to the insulation.

Sleeving Over Cup Terminals. When the connector is to be potted, a protective sleeve over the wire and terminal is not required. If the connector is not potted, the connections should be protected by clear, flexible vinyl tubing or sleeving. The sleeving should not be slid down over the terminal until after cleaning and inspection.

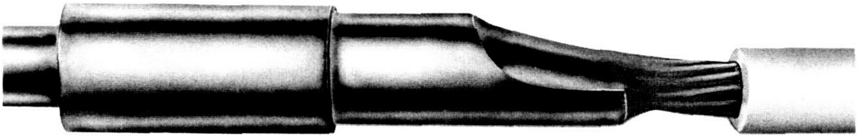

FIGURE 19. Proper solder cup termination.

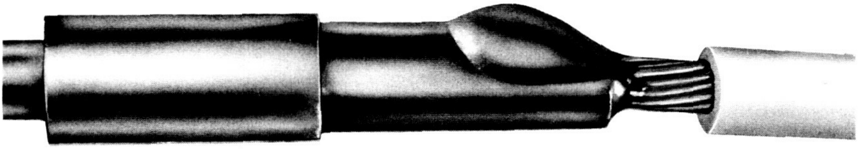

FIGURE 20. Improper solder cup termination.

Protection of Connectors. Since connectors are an important, delicate part of electronic equipment, probes of any kind should never be used for testing. A mating connector or a test box should be used. Plastic or metal dust covers should be installed and maintained on all connectors at all times and should be removed only when required by inspection or connecting to the mating part. They should be properly reinstalled after inspections.

Swage Cup Terminals

Bottom Entry. When the tinned conductor is inserted into the terminal from the bottom, it should be stripped far enough that the insulation does not extend into the barrel ($\frac{1}{32}$-inch minimum clearance is recommended). It should be bent through the side slot, extending a maximum distance of 0.03 inch, and soldered.

Top Entry. The insertion of conductors into the top of the swage cup is the same as insertion into a solder cup terminal except that the conductor should bottom on either the bottom route conductor or the cup bottom. See figure 21.

Bifurcated Terminal Connections

The common methods of inserting conductors into a bifurcated terminal are the bottom route and the side route. If top entry must be used, provisions should be made to obtain good solder fillets to both prongs of the terminal.

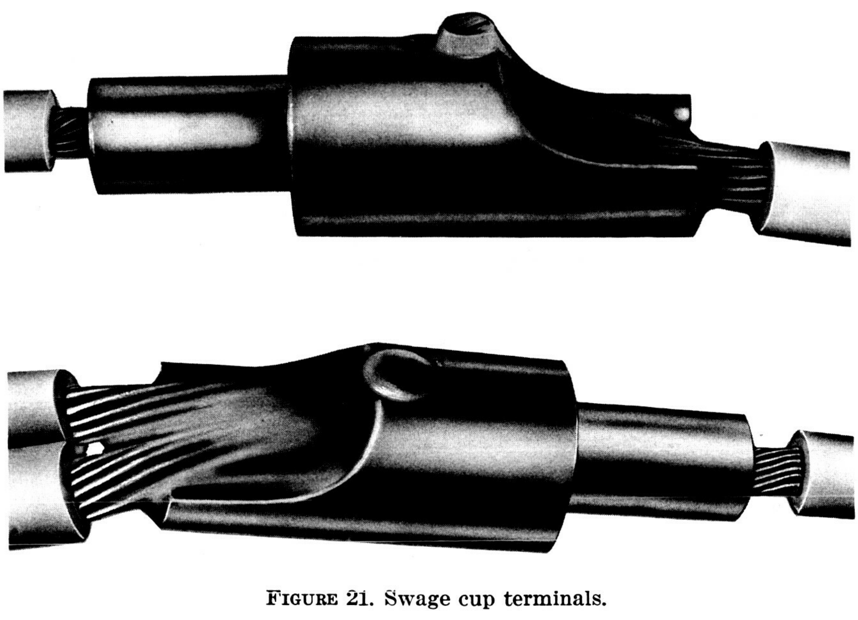

FIGURE 21. Swage cup terminals.

Bottom Entry. When the tinned conductor is inserted into the terminal from the bottom (fig. 22), it should be stripped far enough that the insulation does not extend into the barrel (1/32-inch minimum clearance recommended).

The wire end should be bent to lie flush against the shoulder or one of the posts.

Side Entry. For side entry, the tinned wire end should be brought through the gap and bent flush against the post (fig. 23). A second wire should be bent in the other direction to lie flush against the other post (fig. 24). Additional wires should alternate similarly. The gap may be completely filled, but under no circumstances should the last wire extend beyond the top of the posts.

Wires smaller than AWG 26 may be wrapped one-half turn around the posts if sufficient side clearance exists.

Top Entry. When conductors must be inserted from the top, the wire should fill the space between the posts so that a fillet is formed to each post. A small diameter wire conductor may be bent into a U shape, provided the combined diameter is sufficient to fill the gap. A filler wire (solid or stranded) may also be used to fill the space (fig. 25).

FIGURE 22. Bifurcated terminal—bottom entry.

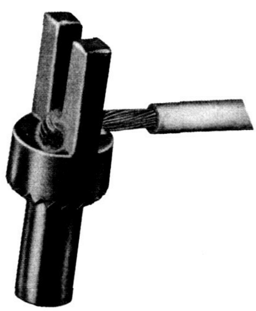

FIGURE 23. Bifurcated terminal—side entry.

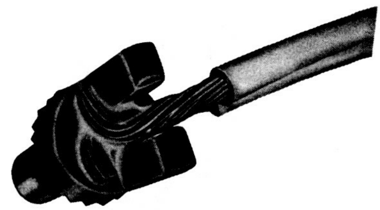

FIGURE 24. Bifurcated terminal—side entry, two wires.

FIGURE 25. Bifurcated terminal—top entry.

Turret Terminal Connections

The end of the conductor should be stripped, tinned, and bent into a loop of approximately one-half turn and slipped over the guide slot, snug against the shoulder (fig. 26). Wires smaller than AWG 26 may be wrapped to a full turn but not to overlap. Wires larger than AWG 26 should not be wrapped more than three-fourths turn.

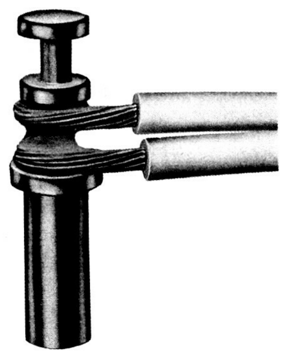

FIGURE 26. Turret terminal.

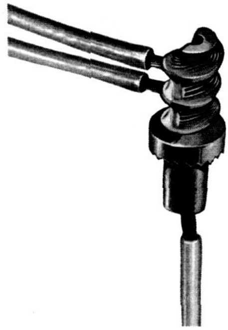

FIGURE 27. Hollow post turret terminal.

When hollow post turret terminals are used, the wire should be stripped to a length that will allow at least 1/32-inch insulation clearance from the swaged end of the terminal. The tinned end of the conductor is brought out the side slot at the top and wrapped as required for the side route (fig. 27).

Storage of Terminals

Terminals should be stored in sealed plastic containers with a small bag of desiccant. Oxidized terminals should not be used.

PRINTED WIRING BOARDS

Board Holders

To prevent damage during assembly and inspection, the wiring board should be held by a fixture to prevent bending, warping, or deformation. A typical fixture (fig. 28) will permit the wiring board to be held at each side and fixed in any desired position.

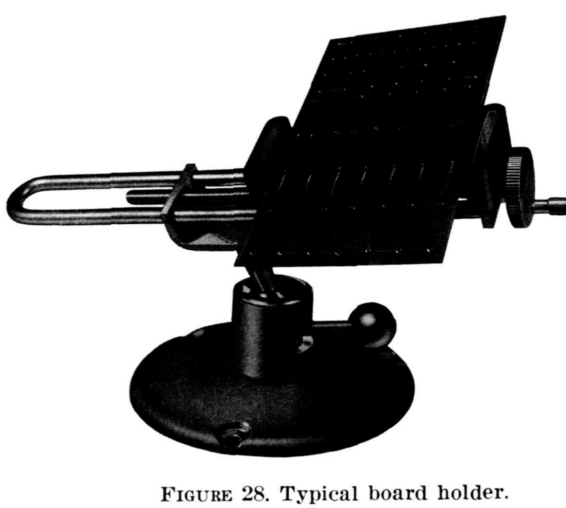

FIGURE 28. Typical board holder.

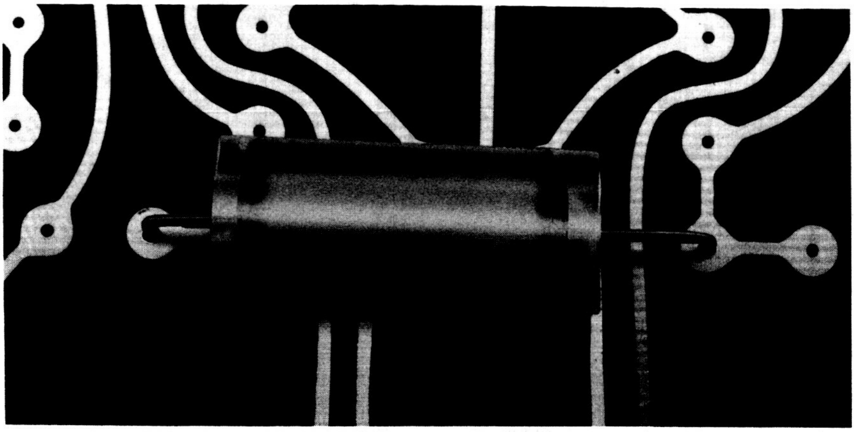

FIGURE 29. Crossing conductor lines.

Printed Wiring Board Care and Storage

Boards should be kept in plastic bags between fabrication processes. After assembly and soldering operations are complete, the boards should be cleaned and inspected. If required, a conformal coating should be applied to both sides of the board. Conformal coating techniques are governed by the type of material used. The work should not be performed in the soldering area.

Boards With Wiring on Both Sides

When parts with conductive cases, such as metal-cased capacitors must be mounted over conductor patterns, the parts should be insulated with transparent tubing (fig. 29).

When a part lead or wire is used to connect pads on opposite sides of the board, the lead or wire must be soldered on both sides.

Bending Part Leads

Round-nose pliers, long-nose pliers with plastic protected jaws, or other suitable tools are recommended for bending the solid wire and part leads (fig. 30). The bending tool should not flatten, nick, or damage the leads. The printed or lettered part identification should be visible after installation.

To prevent cracking of the end seals of a part body, the leads should be bent at a distance equal to twice the lead diameter away from the part body. See figure 31 for proper and improper bends.

The minimum inside radius of the bend should be equal to a lead diameter.

After insertion, the part leads should be cut to the proper length and clinched. When the lead is to be soldered to a circular termination area, the clinch lead length should be equal to one to three times

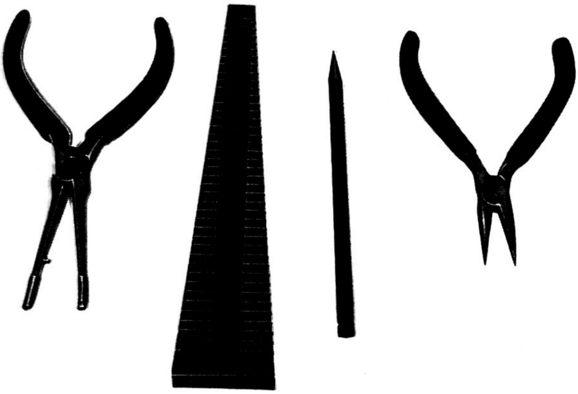

FIGURE 30. Typical bending tools.

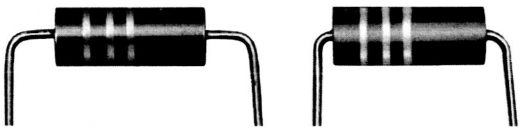

FIGURE 31. Proper lead bends (left), and improper lead bends (right).

the radius of the pad. When the termination area is irregularly shaped, such as for shield and ground plane connections, the clinch lead length should be equal to two to four times the hole diameter. The lead should be clinched in such a direction that it does not overhang the edge of the pattern; on round pads this is parallel to and along the circuit pattern (fig. 32). The end of the lead should be clinched with a nonmetallic clinching tool so it lies approximately parallel to the board surface, the natural spring back of the lead material being acceptable.

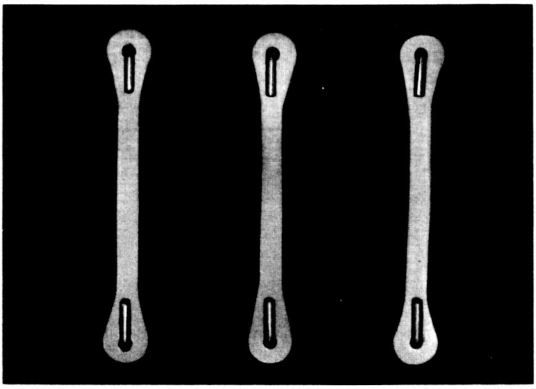

FIGURE 32. Properly clinched leads.

Part leads which cannot be bent or clinched, should be cleaned and tinned and then cut to a length that will allow the end of the lead to protrude from 1/32 to 3/32 inch beyond the solder pad. The parts should be securely mounted to the board with clamps, or embedded in epoxy resin. The solder should form a fillet, but should not obscure the contour of the lead (fig. 33).

Removing Gold Plating

Gold plating must be removed from the areas to be soldered immediately prior to soldering. An approved method of gold removal from pads is to use a white typewriter eraser (pencil shaped), applying light pressure to the pad until the base metal is exposed. Gold particles and eraser crumbs should be removed to avoid contamination.

Handling

Cleaned wiring boards, terminals, part leads, etc., should not be touched with bare hands. When handling is unavoidable, clean finger cots or white gloves should be used.

Soldering Printed Wiring Boards

Soldering to printed wiring boards should be accomplished only on base metal, hot tin-lead coating, or on tin-lead electroplated reflow surfaces.

It is essential that the soldering iron be of the correct wattage and tip shape, and temperature controlled.

Satisfactory joints can be produced on printed wiring boards in the following manner: The soldering iron is held at approximately 45°, the tip of the iron making contact with both the lead and the pad. A small amount of fresh solder is applied to the tip of the iron at the intersection of the lead and tip to promote heat transfer. Then the solder should be moved quickly to the opposite side of the lead and continued in a circular motion from the tip of the lead toward the back of the pad until a proper amount of solder is deposited.

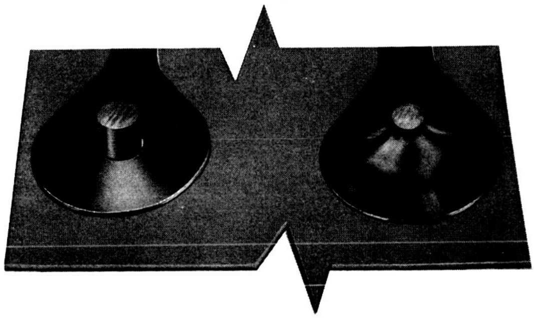

FIGURE 33. Unbendable lead.

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The finished connection should have a smooth even fillet on both sides of the clinched lead. See figure 34. Figure 35 shows the appearance and cross sections of good solder joints.

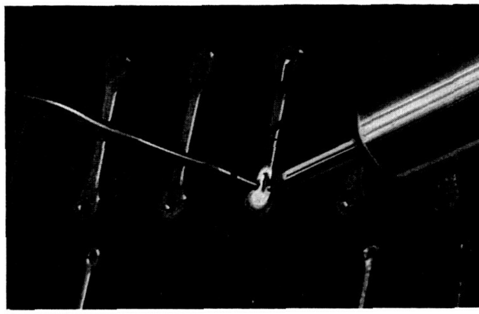

FIGURE 34. Soldering method for printed wiring board.

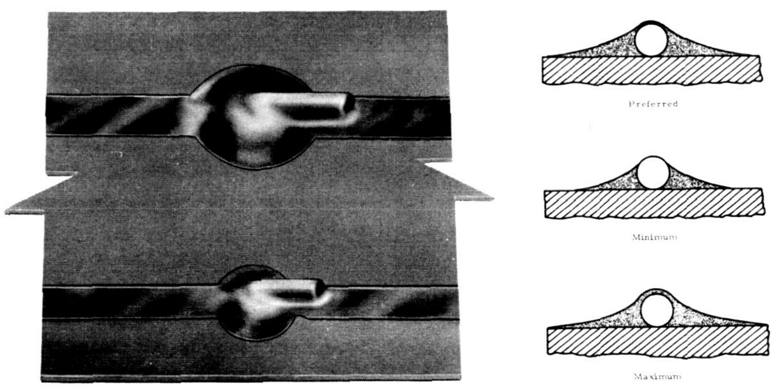

FIGURE 35. Acceptable solder joints.

Part Mounting

Tubular parts or parts with a flat surface should be mounted parallel to and in contact with the surface of the wiring boards. Transistors mounted vertically should be positioned on special pads to allow room for a slight "C" bend which is necessary for stress relief. Odd-shaped parts should be mounted in clamps or embedded in potting compound (fig. 36).

Heavy Parts

Parts that weigh more than ¼ ounce per lead should not be supported by leads only, but should have a suitable clamp or bracket or be embedded in epoxy.

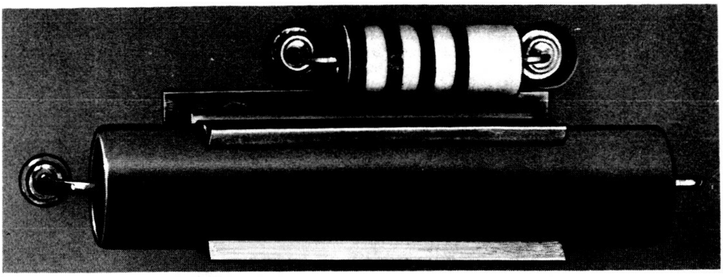

FIGURE 36. Part mounted in clamp.

Mounting and Soldering Terminals

When mounting and soldering terminals to printed circuit wiring boards, the following procedure should be followed:

1. Drill the pad hole to a diameter that will permit the terminal shank to be pressed through the board by hand. A press fit is not necessary, but the terminal should fit snugly enough to prevent it from falling out (fig. 37).

2. Remove gold plating from the terminal area; do not remove tin-lead coating.

3. Solder rings, if used, should be placed over the shank prior to swaging.

4. Swage the terminal with a funnel "V" swage (fig. 38).

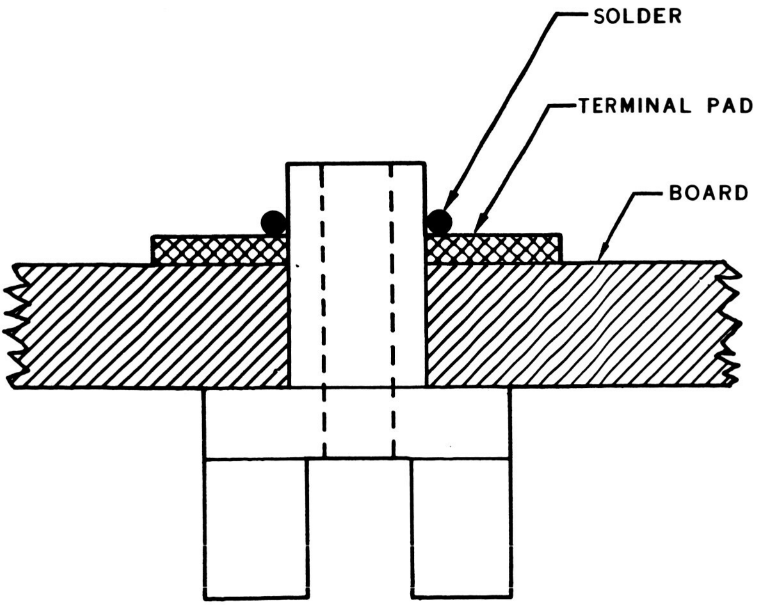

FIGURE 37. Terminal insertion.

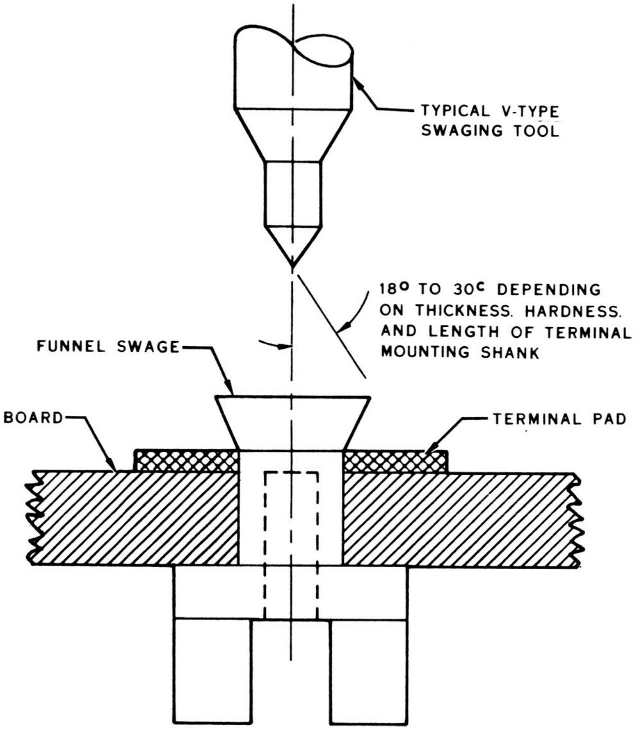

FIGURE 38. Typical swage tool and swaged terminal.

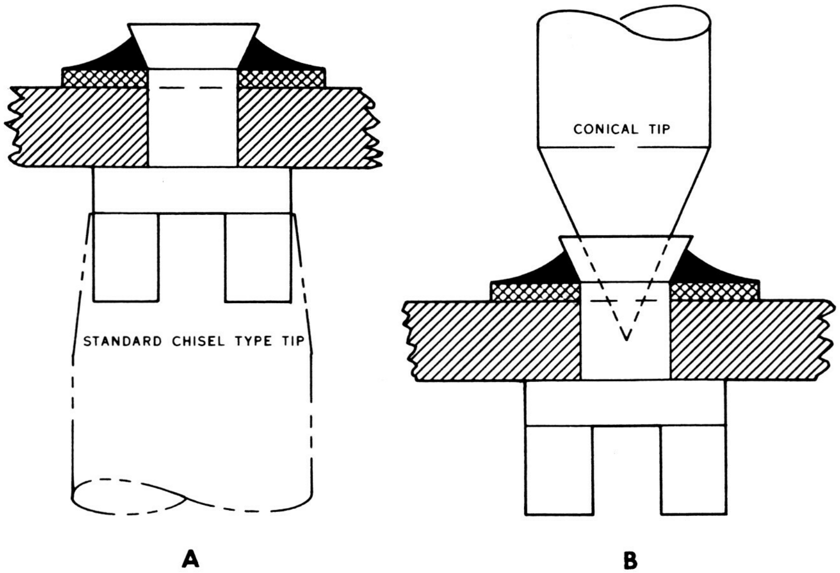

FIGURE 39. Soldering a swaged terminal. An alternate method is shown on the right.

5. Apply a soldering iron with a well-tinned spade tip to the terminal head so that the whole terminal is heated. Apply solder in the angle between funnel and pad so that it flows completely around the funnel to form a smooth fillet. An alternate method is the use of a conical tip inserted into the swage funnel (fig. 39).

6. If the shoulder of the terminal is in contact with the wiring pattern, it should be soldered with a fillet completely around the barrel of the terminal.

7. Clean the flux from the joint, using a solvent and industrial tissue.

SECTION 2

Automatic Machine Soldering

GENERAL

Experiments have proven that reliable solder connections can only be produced after removal of the oxide and other impurities from the metal surfaces to be joined. This permits the molten solder to form an alloy (intermetallic) with the metal surface. When a machine solders all connections on a printed wiring board automatically, correction or rework cannot be made during the solder operation. It is therefore essential that printed wiring boards and lead material be carefully prepared for automatic soldering to prevent costly and time-consuming repairs.

OPERATION AND MAINTENANCE

Automatic soldering equipment produced by different manufacturers, from semiautomatic to fully automatic, varies in characteristics and application. Because of these differences, it is impossible to establish uniform procedures for operation and maintenance. It is recommended therefore that personnel assigned to operate and maintain this equipment follow the installation and maintenance instruction provided by the manufacturer.

EQUIPMENT

Standard automatic soldering equipment consists of the soldering unit, infrared heat bank, transfer mechanism, and board carrier. Additional equipment may include an oil injection adapter, a flux applicator, and precleaning and postcleaning units.

PREPARATION OF PRINTED WIRING BOARDS

After fabrication and cleaning, the printed wiring boards should receive a hot tin-lead coating or an electrodeposit tin-lead plating. Boards with electrodeposit tin-lead must be reflowed with hot oil at approximately 500° F. to establish an intermetallic face between the alloy and base metal. The coating and plating material should be of the same composition as the alloy used during the solder operation. After the coating or plating operation, the printed wiring boards should be cleaned with a specified solvent and stored in plastic bags or boxes until assembly.

PARTS MOUNTING

Part leads should be cleaned and then retinned with the same alloy used during the solder operation. If it should become necessary to touch the areas to be soldered or the part leads, white gloves, or finger cots are recommended to avoid contamination. Part leads should be clinched along the conductive pattern (without overhanging) in such a manner as to prevent movement during the solder operation. Heavy parts, or parts with nonbendable leads should be secured with a coating material or clamp to prevent them from moving while traveling through the machine.

LOADING THE CARRIER

The carrier should be cleaned prior to loading. Care should be taken to avoid contamination of the board during the loading operation. The carrier with the mounted boards should be carefully alined horizontally in relation to the solder wave and should be secured firmly enough to prevent shifting when passing through the solder wave. The loaded board carrier should be mounted on the conveyor so that the leading edge of the board is 1° to 2° above the trailing edge with reference to the horizontal. To avoid warping or bending, excessive pressure to the sides of the printed wiring boards should be prevented.

SOLDERING

Before soldering, the printed wiring board should be given a thin, uniform film of flux, applied either automatically by the flux applicator or manually by spraying, brushing, or dipping. Preheating of the fluxed board is also necessary. The preheating temperature should be controlled to a selected point between 160° F. and 190° F. and should be maintained within ±5° F.

The conveyor speed should be controlled to a preselected rate which should not vary more than 1 inch per minute. The solder wave should have a uniform rate of continuous flow and should be adjusted in such a manner that the wave is in contact with all points to be soldered. The solder temperature of the solder wave should be controlled to 500° F. ±10° F.

POSTCLEANING

All trace of flux and contaminants should be removed from the printed wiring board and parts with an approved solvent either automatically or manually.

INSPECTION

Machine solder boards should be inspected to the same criteria as hand solder boards. Warp or twists should not exceed design requirements.

PROTECTION OF FINISHED PRINTED WIRING BOARDS

Finished boards should be protected by plastic bags or boxes in all processes prior to assembly.

Termination of Shields by Soldering

GENERAL

Shielded wire is used to protect the conductor from outside electrostatic or electromagnetic interference. This shielded wire generally consists of a plated copper conductor or conductors with appropriate insulation and covered by a wire mesh. Termination of the shields should be performed by one of the following methods.

SINGLE CONDUCTOR SHIELD TERMINATION

The shield is marked at the point where the conductor will break out. The shield is loosened by pushing it from the end toward the breakout point. A hole (large enough to pull the conductor through) is made with a pointed tool at the breakout point (fig. 40). The individual shield strands should not be damaged, and the shielding should be pulled tight to smooth out the shield (fig. 41).

When a shield termination is not required, the loose end of the shield is cut to approximately $\frac{1}{4}$ inch. The end is then bent back along the shield, and a length of tubing is fitted over the shield end to prevent raveling and slipping (fig. 42.).

FIGURE 40. Shield breakout.

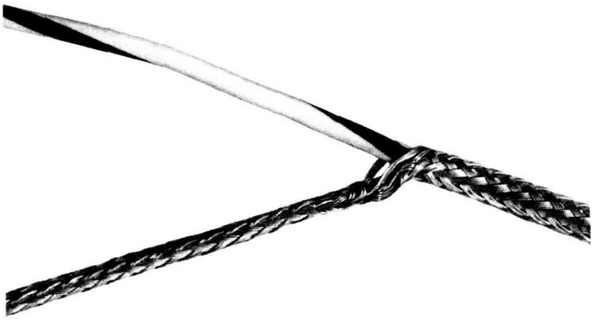

FIGURE 41. Shield smoothed out.

FIGURE 42. Shield without termination.

SOLDER SLEEVE TERMINATION

The high-temperature solder sleeve consists of a heat shrinkable, nonflammable, polyvinylidene fluoride sleeve, containing a preform ring of fluxed solder at the middle, and a thermoplastic sealing ring in each end (fig. 43). This device can be used to terminate shields on high-temperature wire only.

The size of solder sleeve should be selected according to the size of the shielding. The stripped and pretinned jumper wire should be positioned toward the connector and parallel to the exposed shield of the conductor.

Before the connection is made, the heat source must be calibrated for the particular size of solder sleeve. The heat source should have the following characteristics: (*a*) Uniform heat delivery to the circumference of the solder sleeve; and (*b*) controlled time. Figure 44 illustrates a typical heat source.

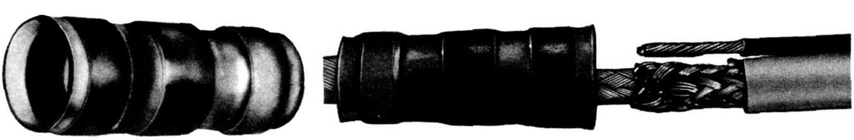

FIGURE 43. Solder sleeve (left), and jumper properly positioned prior to placing solder sleeve.

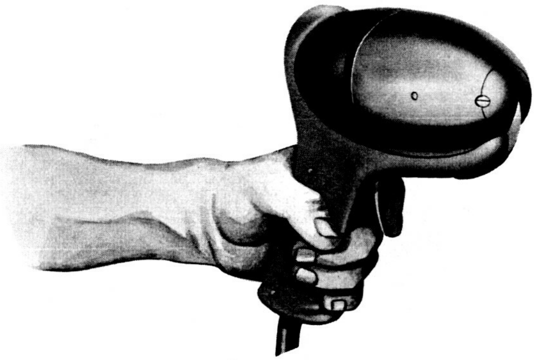

FIGURE 44. Typical heat source.

The connection should be made as follows. Slip the solder sleeve over the conductor and jumper wire, visually ascertaining that the solder ring is centered over the stripped portions. When the position is correct, apply heat until the solder melts and the plastic shrinks to final dimensions.

NOTE

Time and temperature are very important factors. Overheating causes damage to conductor insulation and disappearance of the solder. Underheating will produce a cold connection characterized by a pileup of solder. A properly heated connection demonstrates uniform flow of solder. (See fig. 45.)

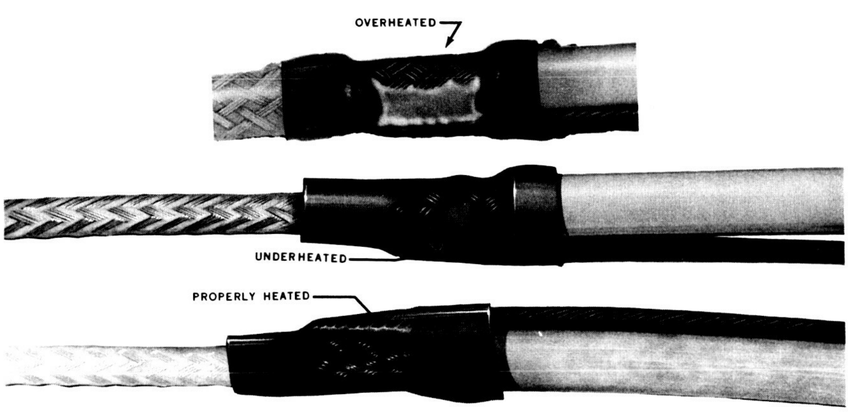

FIGURE 45. Solder sleeve terminations: overheated, underheated, and properly heated.

SECTION 4

Lacing of Cable Trunks

GENERAL

To prevent damage to insulation and breaking of conductors caused by vibration and other movements, the wires must be tied together in bundles or harnesses and secured to the structure or to a tiebar. Various methods such as continuous lacing, spot ties, plastic cable ties, plastic tubing, and spiral-wrapped plastic tape are commonly used for lacing the cable trunk. Excessive tension, visible as a deformation of the outside diameter of the cable trunk, will promote cold flow of the insulation under the tie. This condition can result in low insulation value or short circuits. Preferred methods of lacing and the use of plastic ties will be discussed in the following sections.

CONTINUOUS LACING

The materials commonly used for continuous lacing are lacing tape, cord, or small diameter tubing.

The stitching should be equally spaced up to the point of branching or other termination (fig. 46). Where the harness ending consists of a single wire or a pair of wires, a clove hitch secured by a square knot is sufficient. In component assemblies where wires break from the cable trunk to a termination, the tie should be made a distance from the branch to provide a sufficient vibration bend (fig. 47).

TERMINATING STITCHES AND SPOT TIES

A clove hitch and a square knot are generally used for terminating stitches and spot ties (fig. 48).

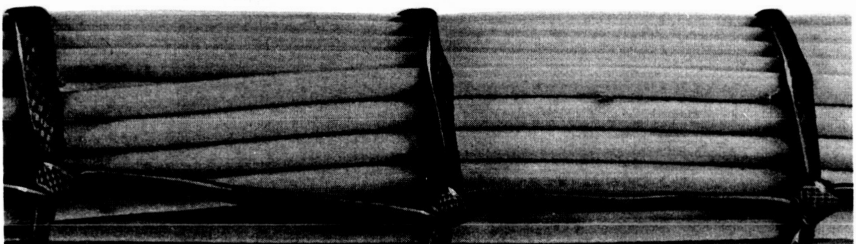

FIGURE 46. Equal spacing.

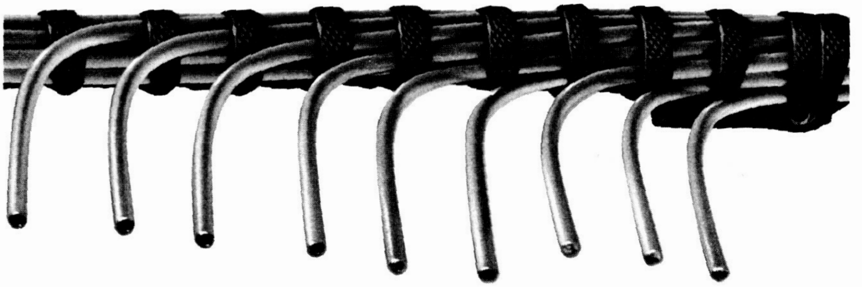

FIGURE 47. Vibration bend.

FIGURE 48. Clove hitch and square knot.

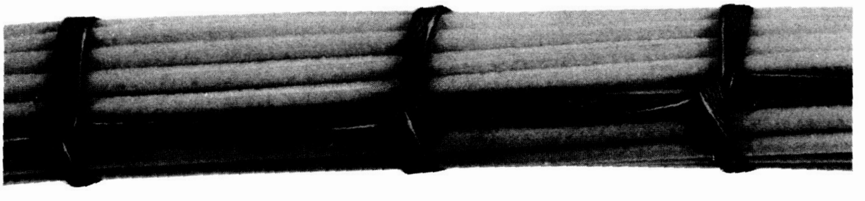

FIGURE 49. Running stitch.

RUNNING OR SINGLE STITCHES

Running or single stitches are successfully used on insulation that has high-potential cold-flow characteristics. It is made by passing the free end of the lacing material around the bundle, over the standing part, and through the loop (fig. 49).

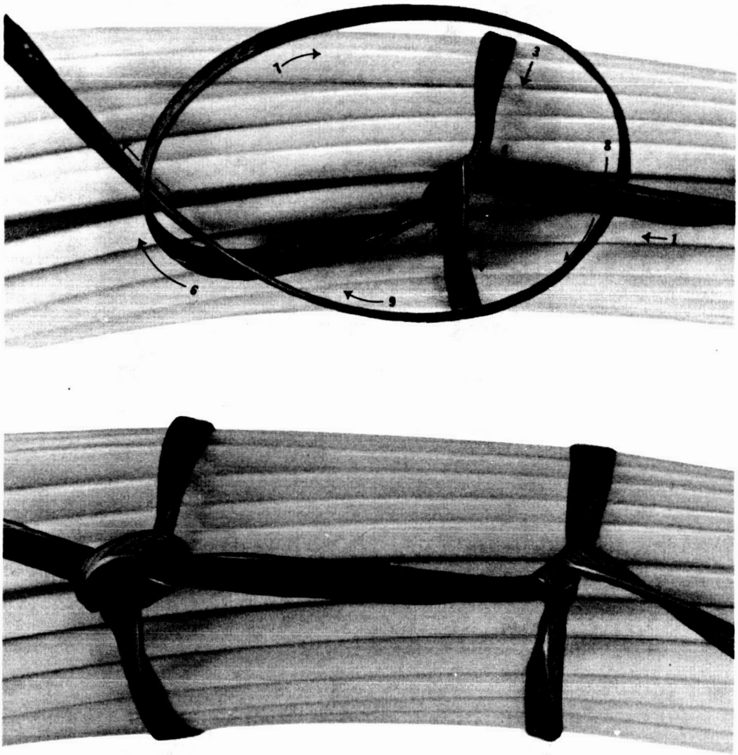

FIGURE 50. Single lock stitch method.

SINGLE LOCK STITCH

The single lock stitch is commonly used for continuous lacing. It is made by making a single stitch, then passing the free end under the lacing between the two stitches and through the loop (fig. 50).

DOUBLE LOCK STITCH

The double lock stitch is used primarily to prevent lacing from loosening but is frequently used for complete lacing. It is made by making two single stitches around the bundle and securing with a lock stitch (fig. 51).

SPACING OF STITCHES

The wires in a finished cable trunk should have a minimum number of crossovers. Crossovers, if necessary, should be at least 8 inches from the termination. Terminating stitches should be made at the end of each lacing. The type of stitch is determined mainly by the type of

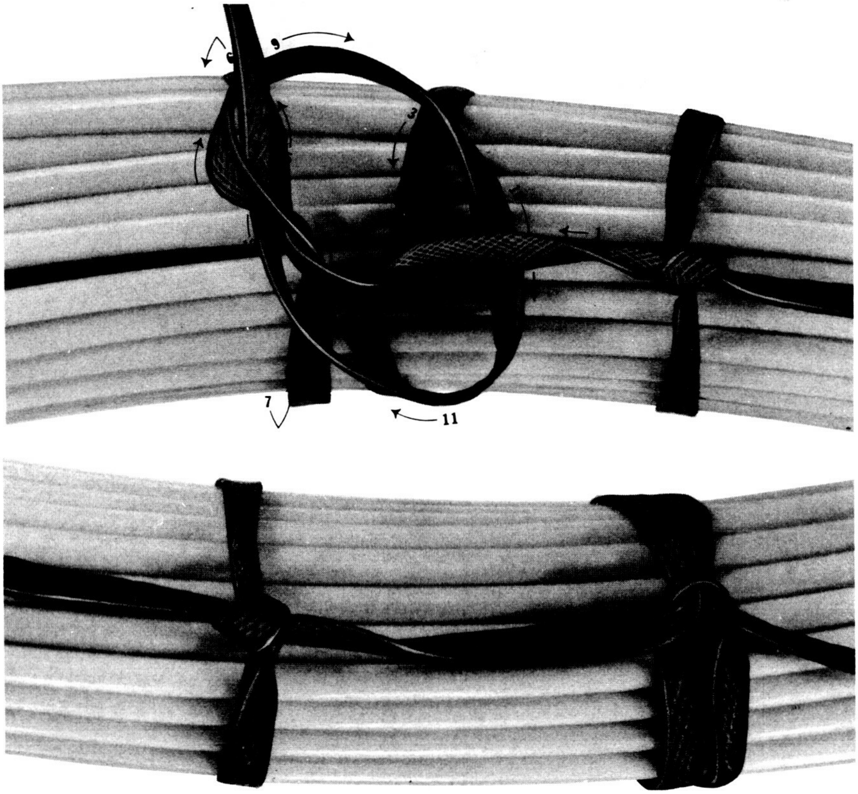

FIGURE 51. Double lock stitch method.

insulation and diameter of the bundle. The most commonly used stitch spacing is indicated in the table below.

Cable or harness diameter:	*Lacing intervals—inches, approximate*
½ inch or less	¾–1½
1 inch	2
Larger diameter	3

Combinations of running stitches may be used on the same harness.

SERVE

The length of the serve or endless tie should be approximately equal to the outside diameter of the wire bundle and should not exceed ¾ inch. To prevent the lacing from loosening, it should be served at the point of origin and at the point of termination of the lacing (fig. 52). The serve is used at bundle branches or breakouts and at all bundle end terminations (fig. 53). The serve is made by forming a loop along the bundle with the lacing tape, keeping the ends of the

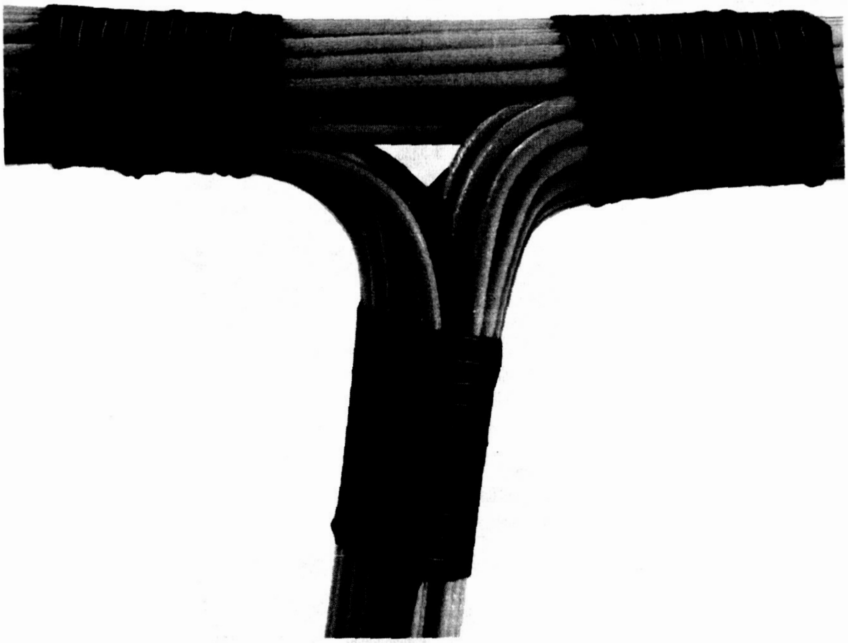

FIGURE 52. Serve at point or origin.

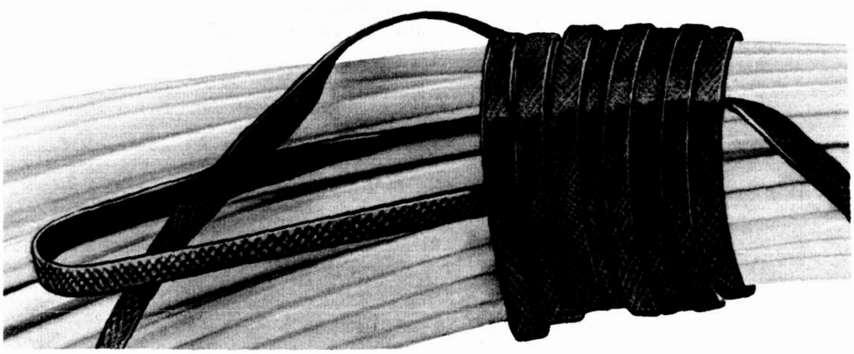

FIGURE 53. Serve method of tying.

tape toward the bundle end. Wrap the lacing end of the tape around the bundle and over the loop. Upon reaching the desired length of serve, pass the lacing end through the loop and pull the ends away from each other. Adjust by pulling until the cross is under the serve. Cut this excess tape from each end of the serve.

SPOT TIES

Spot ties are frequently used in place of continuous lacing. These are made exactly like the termination ties (fig. 54).

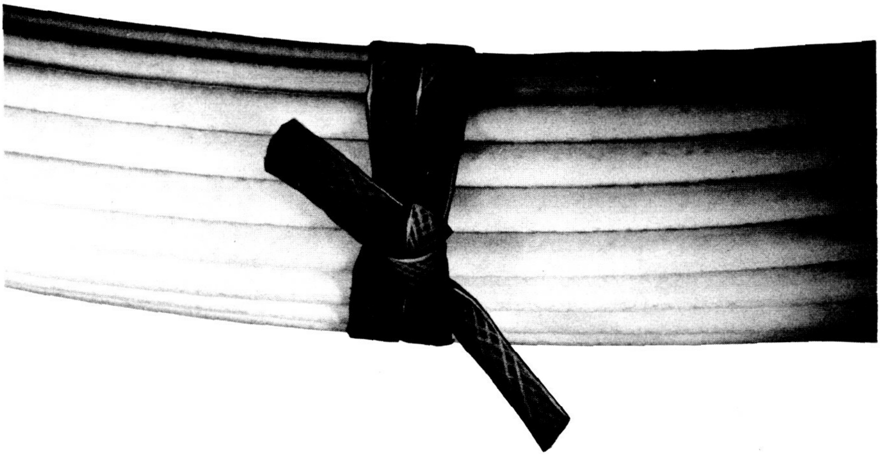

FIGURE 54. Spot tie.

PLASTIC CABLE TIES

In some applications, plastic (usually nylon) cable ties are used instead of lacing cord or lacing tape. The ties should be assembled around the harness with the ribbed side down and the strap pulled through the boss. The straps should then be tightened to a predetermined tension with a locking tool calibrated for the size of the cable tie used and the type of wire insulation. The tool should be calibrated such that the finished tie does not reduce the outside diameter of the cable trunk (figs. 55 and 56).

> ***CAUTION***
>
> Cut the end of nylon straps off flush with the boss to avoid cuts to hands from the sharp edges. The plastic ties may also be used as cable clamps. Care should be taken that no cable clamp be placed over a cable tie.

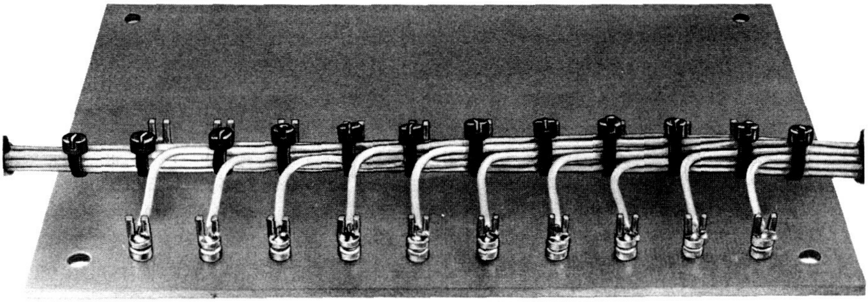

FIGURE 55. Finished tie.

FIGURE 56. Typical locking tool.

SERVICE LOOPS

Where a loop must be provided to allow opening of an access door, the harness should be served at the start and end of the loop. The loop should not be laced, but should be secured by spot ties or plastic cable ties (fig. 57).

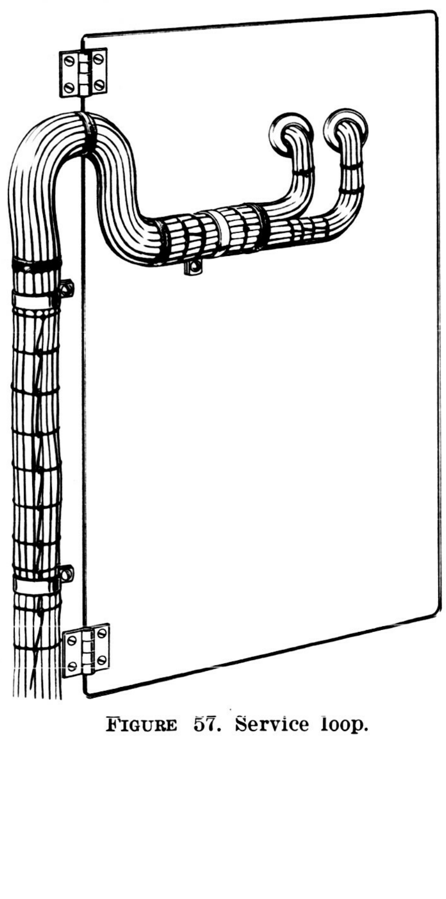

FIGURE 57. Service loop.

Color Codes

APPENDIX A

Color	Digits or No. of Zeros	Resistors RMA or JAN		Capacitors Molded Mica RMA and JAN			Capacitors Molded Paper		Capacitors Ceramic				Color	Digits or No. of Zeros
		Multiplier	Tolerance	Multiplier	Tolerance	Class or Characteristic	Multiplier	Tolerance	Multiplier	Tolerance C 10 $\mu\mu f$	Tolerance C 10 $\mu\mu f$	PTS/Mil/°C		
BLACK	0	1		1	20%	A	1	20%	1	20%	2.0	0	BLACK	0
BROWN	1	10		10		B	10		10	1%		−30	BROWN	1
RED	2	100		100	2%	C	100		100	2%		−80	RED	2
ORANGE	3	1000		1000	3% (RMA)	D	1000		1000	2.5% (RMA)		−150	ORANGE	3
YELLOW	4	10^4		10^4		E	10^4	5%	10^4			−220	YELLOW	4
GREEN	5	10^5			5% (RMA)	F (JAN)				5%	0.5	−330	GREEN	5
BLUE	6	10^6				G (JAN)						−470	BLUE	6
VIOLET	7	10^7										−750	VIOLET	7
GRAY	8	10^8				I (RMA)					0.25	+30	GRAY	8
WHITE	9	10^9				J (RMA)		10%		10%	1.0	*	WHITE	9
GOLD		0.1	5%		5% (JAN)		0.1	5%					GOLD	
SILVER		0.01	10%		10%			10%					SILVER	
NO COLOR			20%					20%					NO COLOR	

*−350 +500 JAN
+120 −750 RMA

FIGURE A–1. Color code designations.

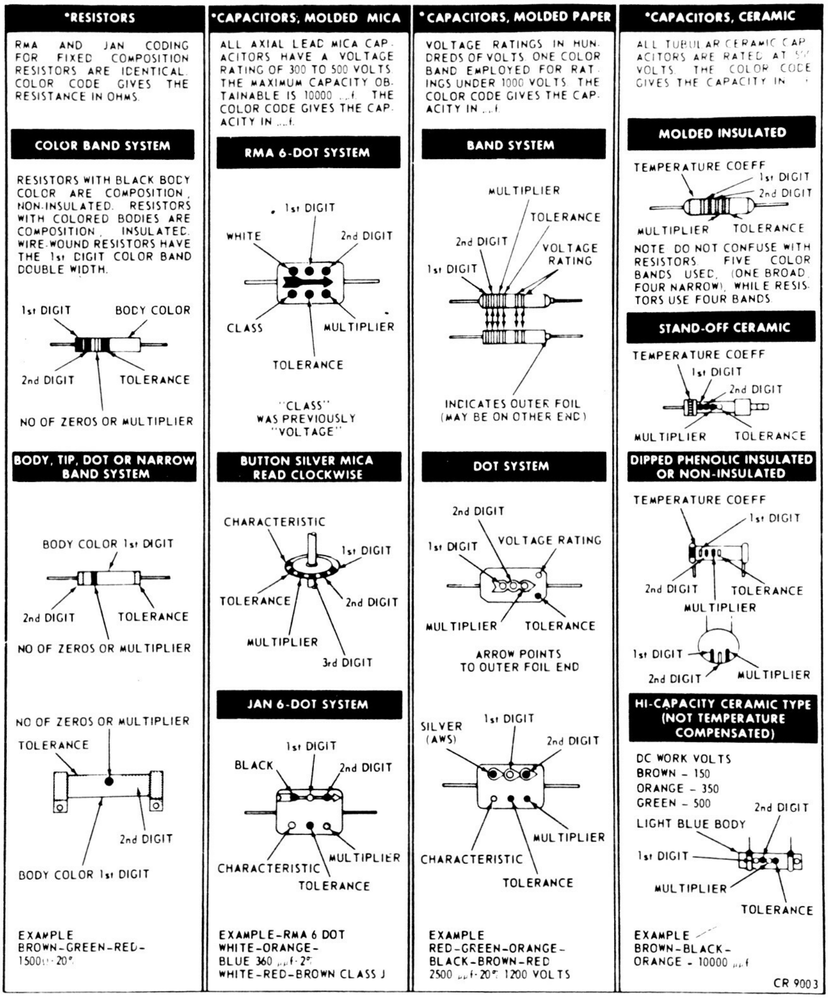

FIGURE A–2. Color codes for resistors and capacitors.

APPENDIX B

Solder Characteristics

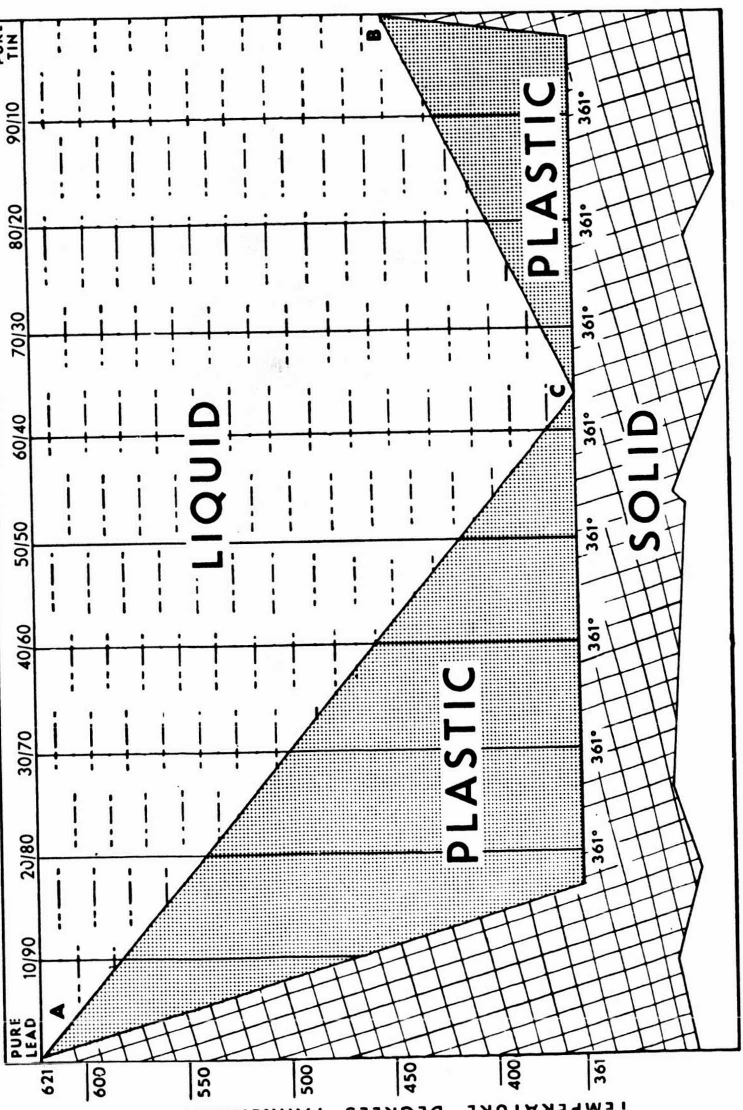

FIGURE B–1. Tin-lead fusion diagram.

				Temperature at which solder becomes plastic		Temperature at which solder becomes liquid	
%Sn	%Pb	%Ag	%Sb	C°	F°	C°	F°
0	100					327	620
5	95			272	522	314	597
10	90			224	435	302	576
15	85			183	361	290	554
20	80			183	361	280	536
25	75			183	361	268	514
30	70			183	361	257	496
35	65			183	361	247	477
38	62			183	361	242	468
40	60			183	361	238	460
45	55			183	361	225	437
48	52			183	361	218	424
50	50			183	361	212	414
55	45			183	361	200	392
60	40			183	361	188	370
63	37			Eutectic		183	361
65	35			183	361	184	364
70	30			183	361	186	367
75	25			183	361	192	378
80	20			183	361	199	390
85	15			183	361	205	403
90	10			183	361	213	415
95	5			183	361	222	432
100	0					232	450
95			5	232	450	238	460
35	63		2	187	369	237	459
27	70	3		179	354	312	594
40	57	3		179	354	289	543
50	47	3		179	354	260	500
61.5	35.5	3		179	354	248	478
62.5	36.1	1.4		Eutectic		179	354
96		4		Eutectic		221	430
95		5		221	430	240	465
	97.5	2.5		Eutectic		305	581
	95	5		305	581	365	689
0.75	97.5	1.75		Eutectic		310	590

A eutectic alloy is that composition of two or more metals that has one sharp melting point and no plastic range. Sn-Tin; Pb-Lead; Ag-Silver; Sb-Antimony.

TABLE B–1.—*Melting temperatures of alloys used in soldering.*

APPENDIX C

Solder Cracking Problems

During early research and development of missiles and rockets, the time from fabrication to launch was short. The printed wiring boards for flight and launch support equipment had circuitry on only one side and were coated with a thin coating of epoxy resin. Solder joints of acceptable configuration did not experience cracking during their rather brief lifetime.

Components for space applications, however, have become more complicated and their required lifetimes have been extended. Environmental requirements have become more stringent. New technological innovations, such as double-sided printed wiring boards with terminals, part leads, and in some applications, eyelets or tubelets interconnecting the two circuits, have come into general use. Polyurethane conformal coating has replaced epoxy resin. With these changes have come problems with cracked solder joints.

Cracked solder joints have been discovered, with alarming frequency, on the printed wiring boards of various types of equipment. This cracking has been found in varying degrees from stress lines to 360° cracks around part leads and terminals.

Tests have revealed that connections under stress will disintegrate at a rate dependent upon the amount of pressure and time. A solder joint that is subjected to no stress will last for an infinite period; a solder joint subjected to stress will inevitably crack, and the greater the pressure the shorter the useful life of the joint.

The effects of cracked joints on circuitry vary from an increase in resistance to complete discontinuity of the circuit.

EVALUATION OF SOLDER CRACKING MECHANISM

A test program was undertaken to investigate the failure mechanism and find ways of preventing recurrence of the problem.

Part Leads

Cracks or serious stress lines have not been observed on single-sided boards without conformal coating. Similarly, cracks or serious stress lines have not been observed on double-sided boards with plated-through holes where part leads were soldered on both sides, either with or without conformal coating.

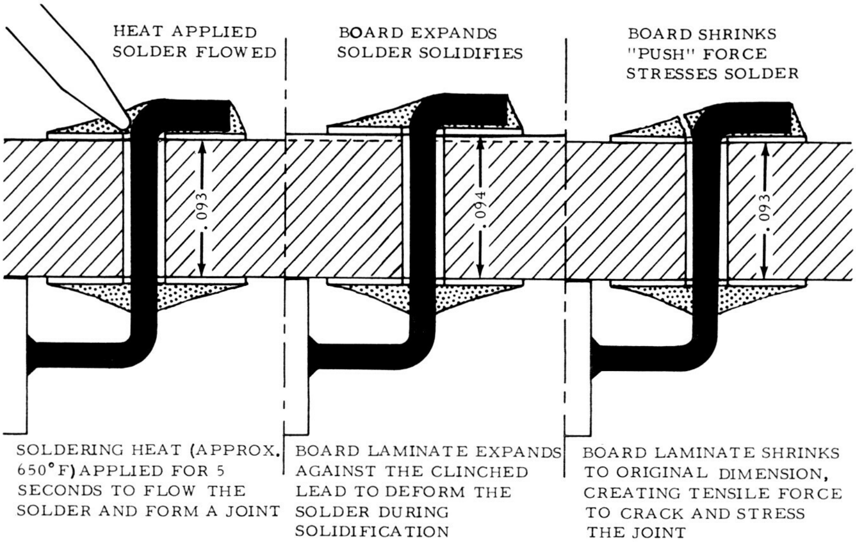

FIGURE C–1. Double-sided board with interconnecting part leads.

NOTE

Cracks, however, have been observed where double-sided boards were interconnected by a part lead (without plated-through holes). See figure C–1.

The investigation revealed that cracking is the result of stresses set up within the joint and contributed to by the external forces of the base material and conformal coating. Figures C–2 and C–3 show a stress line at the periphery of a lead hole. Figure C–4 shows the deformation of the crystal structure in a stress line and the beginning of a crack. The following configurations have experienced cracking:

1. Kovar leads with all types of spacers, polyurethane conformal coated, and no stress relief provided.
2. Brass leads, in combination with polyurethane conformal coatings, and no stress relief provided.
3. Nickel leads, protruding from encapsulated modules, mounted flat on the board, in combination with conformal coating, and no stress relief provided.
4. Bent leads, connecting double-sided conductor patterns, without stress relief, and without plated-through holes.
5. Brass terminals, swaged and soldered to interconnect the two circuits on double-sided printed wiring boards, and no conformal coating.

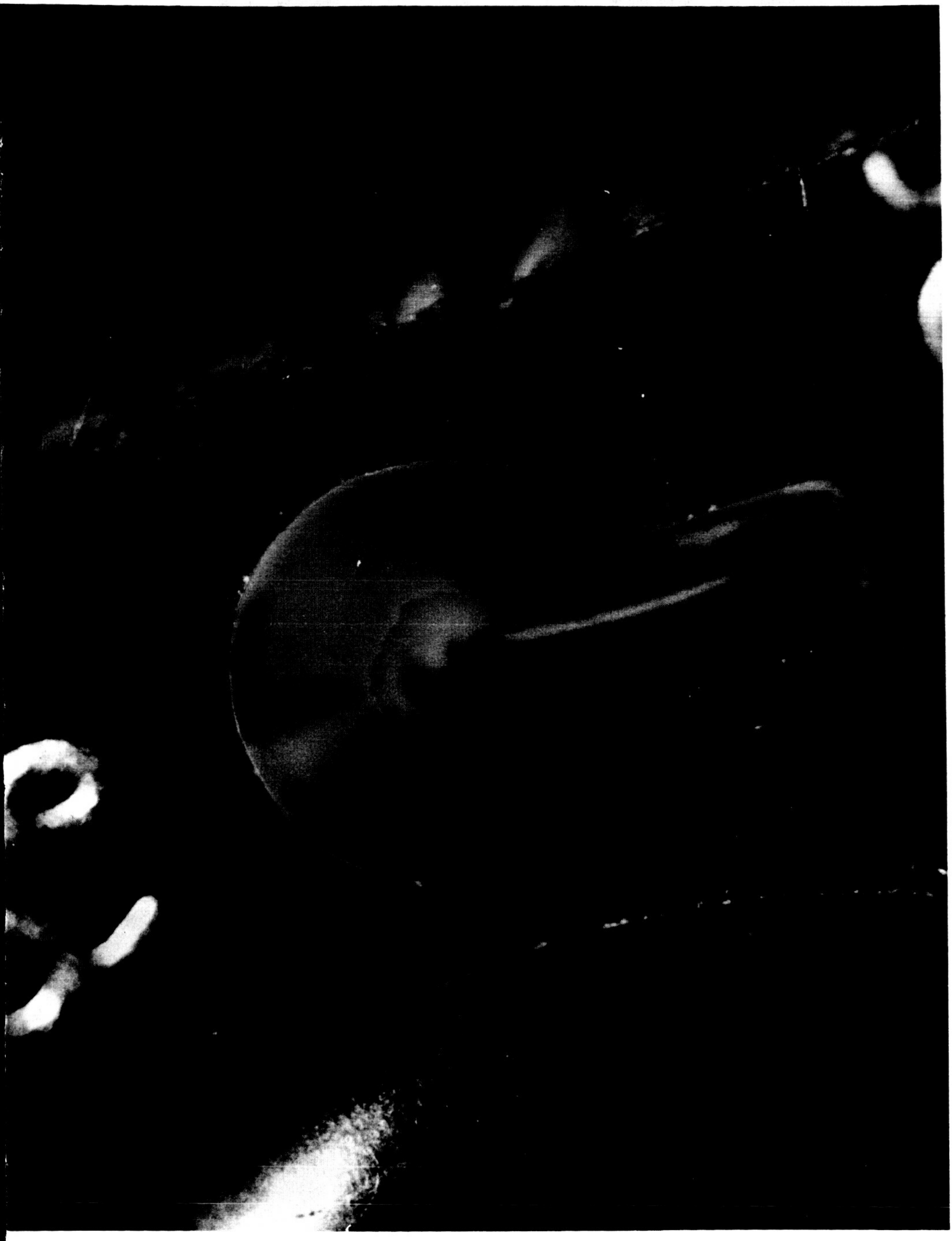

FIGURE C–2. Stress line.

FIGURE C–3. Stress line.

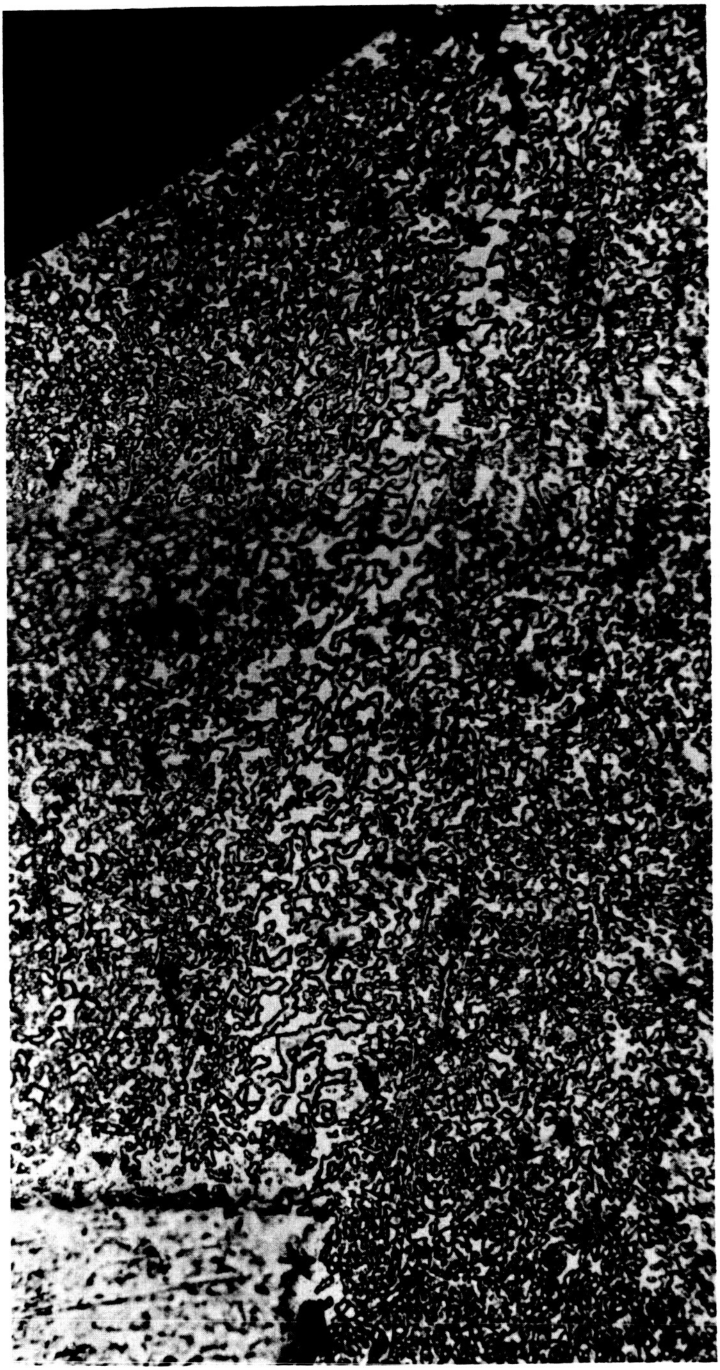

FIGURE C–4. Microphotograph of stress line and beginning of a crack.

Cracks have not been observed on hand-soldered transistor leads when the transistors were flush mounted on single-sided boards, even though they were conformal coated. Flush mounting, however, can create another problem. When the assembly moves over the solder wave, hot air compressed in the lead holes blows the solder out, leaving voids in the joint. It is recommended therefore that, in machine soldering operations, transistors be mounted so that air can escape from beneath the part.

Transistors without stress relief, mounted on short spacers, and conformal coated, had the most destructive effects on soldered connections. Figures C–5 and C–6 show cracks occurring in the thin bridged area at the periphery of a lead hole. This mounting configuration was restrained by the coating during contraction-expansion, forcing the leads in a direction normal to the surface of the printed wiring board, and generating stresses in the soldered joints.

FIGURE C–5. Crack at periphery of lead hole.

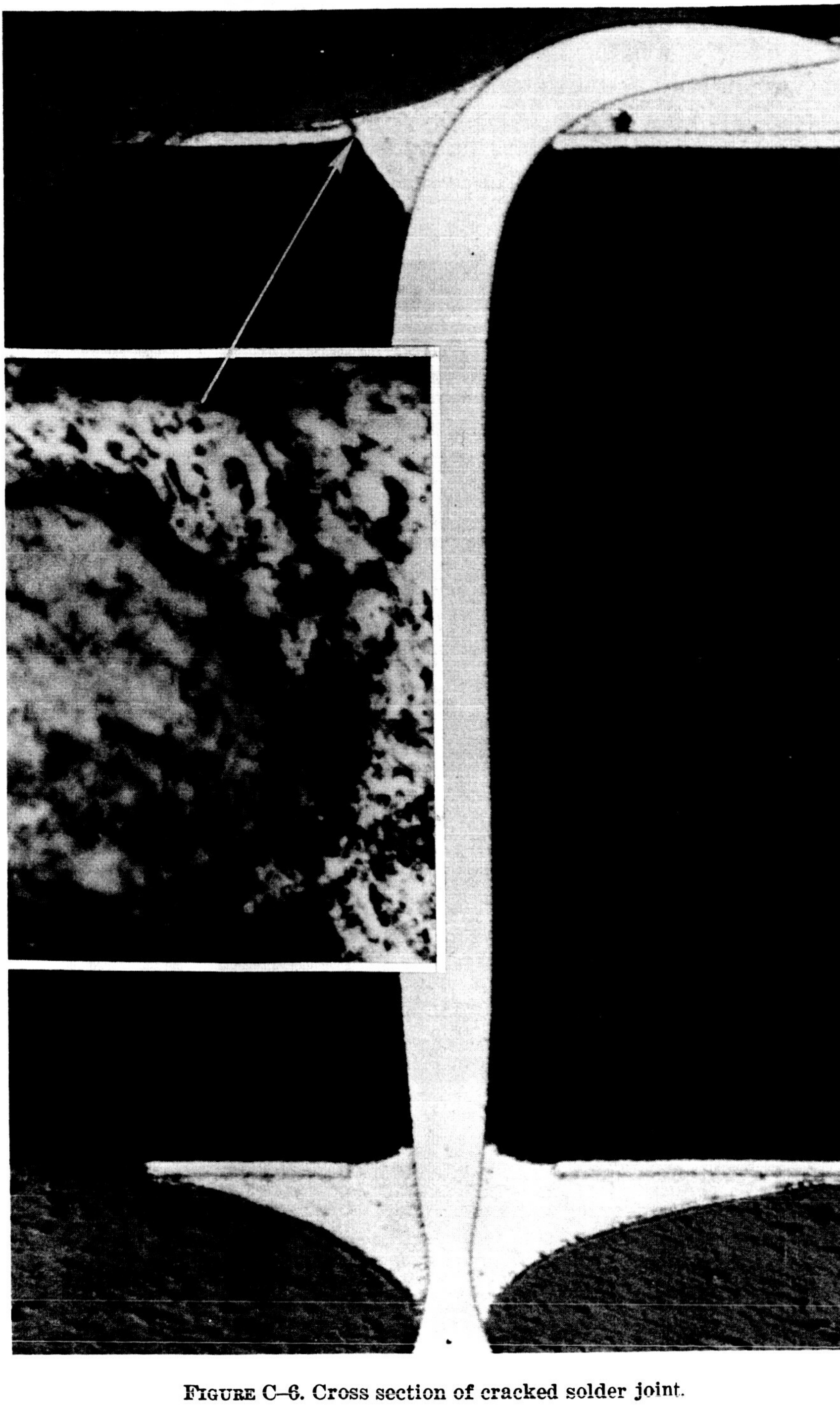

FIGURE C–6. Cross section of cracked solder joint.

Stresses and cracks have been found on other parts, usually when the lead material was hard and/or large in diameter. Figure C–7 shows surface indications of extensive stressing. The microphotograph of the joint (figure C–8) shows the crack at the interface of the lead and the solder. These parts had all been mounted above the board high enough to allow polyurethane conformal coating to flow under the part.

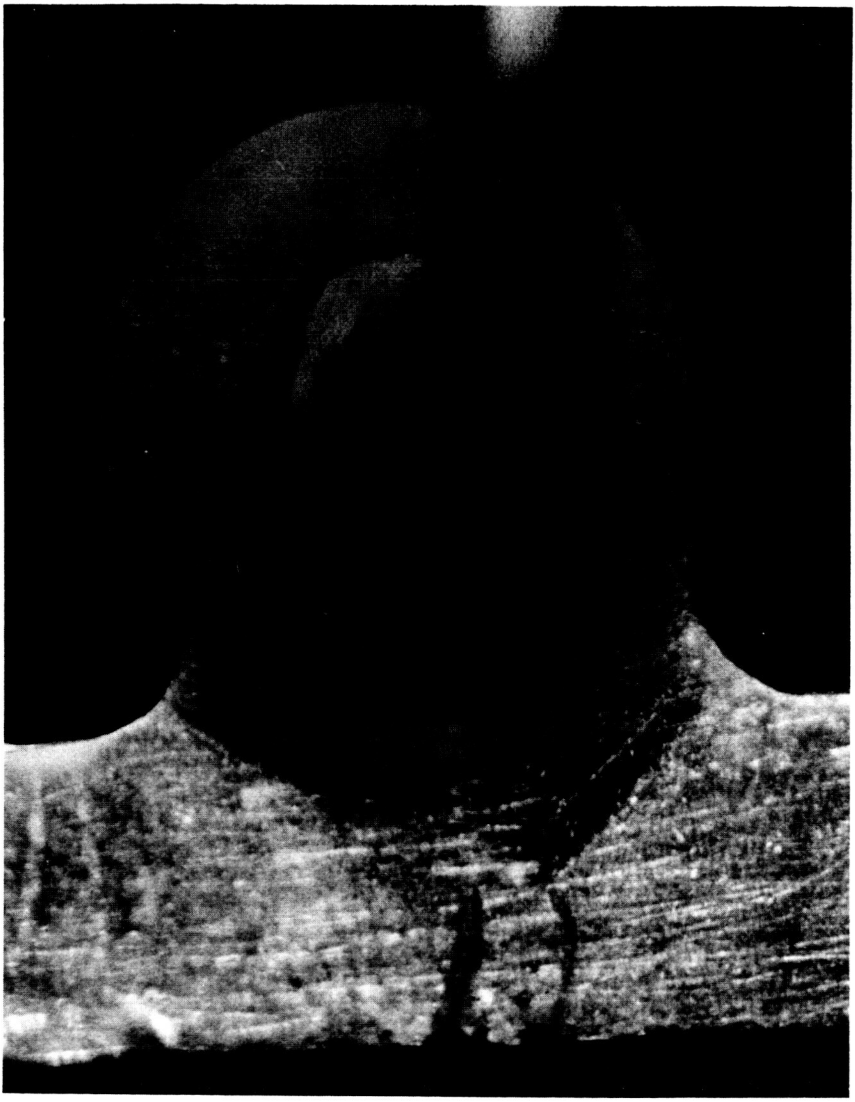

FIGURE C–7. Surface indications of stressing.

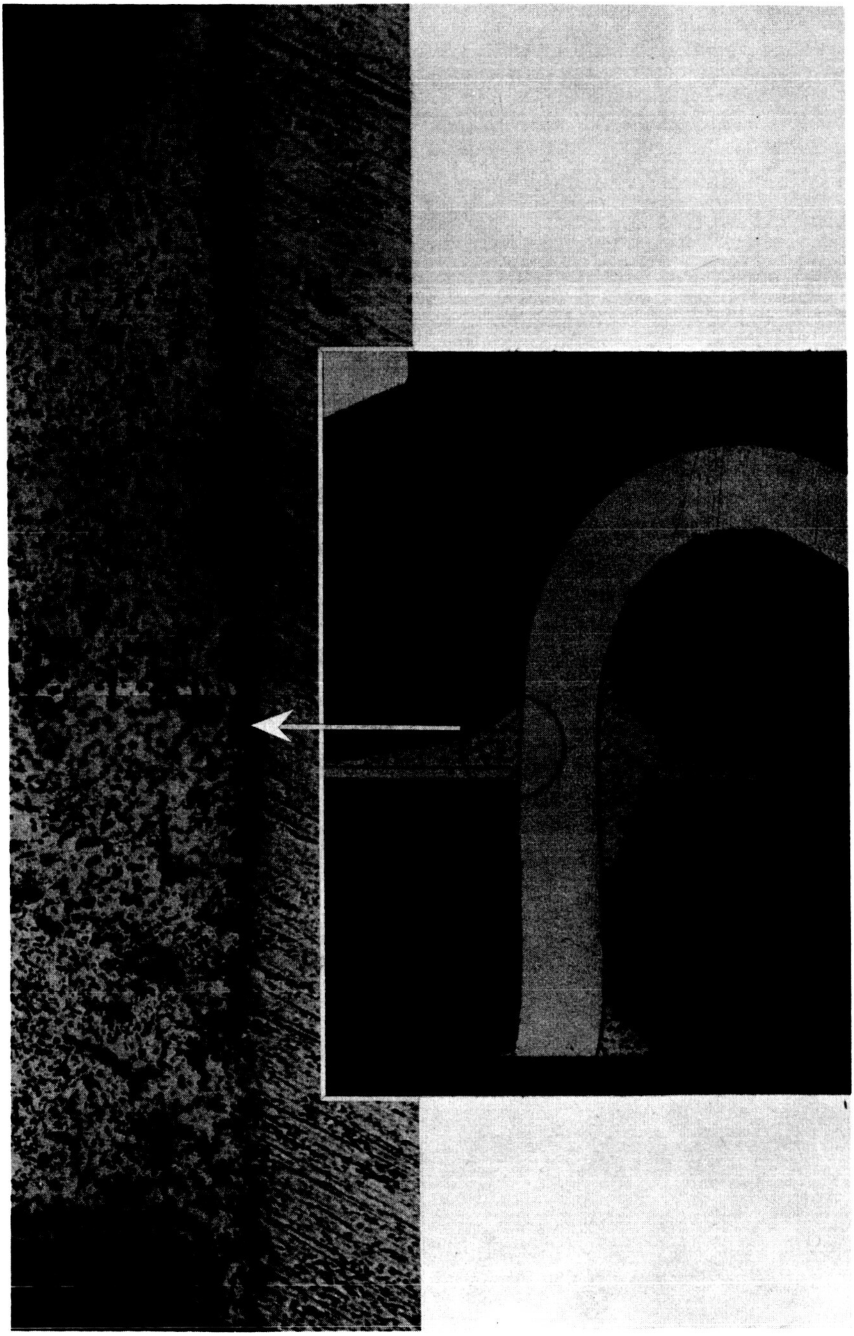

FIGURE C–8. Crack at lead-solder interface.

The cracking mechanism can be explained as follows: After completion of the solder operation, the board is conformally coated, the coating penetrating under each part. The curing temperature expands both the board material and the conformal coating. Cooling to room temperature causes shrinkage of the materials. This expansion-contraction applies stresses to the soldered connections. Subsequent temperature changes will finally destroy the joint.

Recommendations based on the findings of the test program are:

1. Provide strain relief in leads of all parts mounted above the board when conformal coating will be required.
2. Use tall (0.150 inch) transistor spacers when spacers are required.
3. Reduce the hole diameter to allow 0.005 inch clearance between lead and hole diameter.
4. Use maximum contour soldering on all connections.
5. Reduce conformal coating thickness to the minimum requirement.
6. When no strain relief can be provided, do not conformal coat beneath the part.
7. Attention should be directed to the following design and manufacturing characteristics:
   (*a*) Stress relief bends or loops in part leads.
   (*b*) The effects of expansion and contraction on materials during temperature cycles.
   (*c*) Solderability of part leads and base material.
   (*d*) Preproduction qualification testing of printed wiring assemblies to their environmental requirements to assure continued reliability.

Terminals

An investigation of the failure mechanism of terminals, swaged and soldered to double-sided boards, was also made. See figure C–9 for test setup.

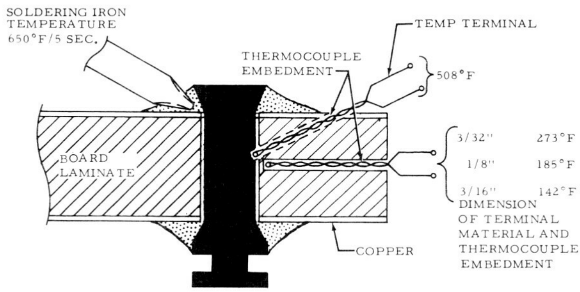

FIGURE C–9. Temperature test setup.

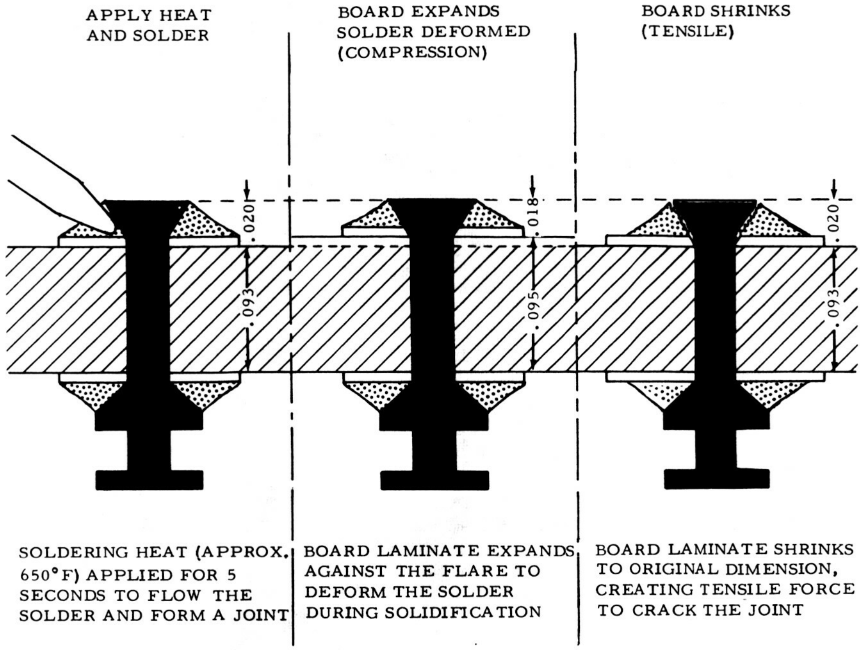

FIGURE C–10. Mechanism of terminal solder joint cracking.

When only one side of the terminal was soldered to the printed wiring board, no stresses or cracks were detected.

During the second soldering operation, on the other side of the board, the following changes in the structure of the materials could be observed.

1. The heat of the soldering iron expanded (lengthened) the terminal. See figure C–10, left.
2. Heat, transferring from the terminal (fig. C–10, center), expanded the surround-board laminate, causing the board to expand at a rate three to six times greater than the brass terminal.
3. The expansion of the board caused deformation of the liquid solder through compression between the pad and the terminal. The joint then set in this deformed condition of maximum board expansion.
4. Upon cooling, the board material and the brass contract to their original configurations, setting up tensile and shear forces, and consequently, a stress/crack potential (fig. C–10, right).

It is concluded that terminals should not be used as interconnections on double-sided printed wiring boards. Figure C–11 and C–12 are micro-photographs showing a swaged terminal connecting a double-sided printed wiring board. The joint has a cracked area adjacent to the terminal which extends completely through the interfacial bond area.

FIGURE C–11. Swaged terminal with cracked solder.

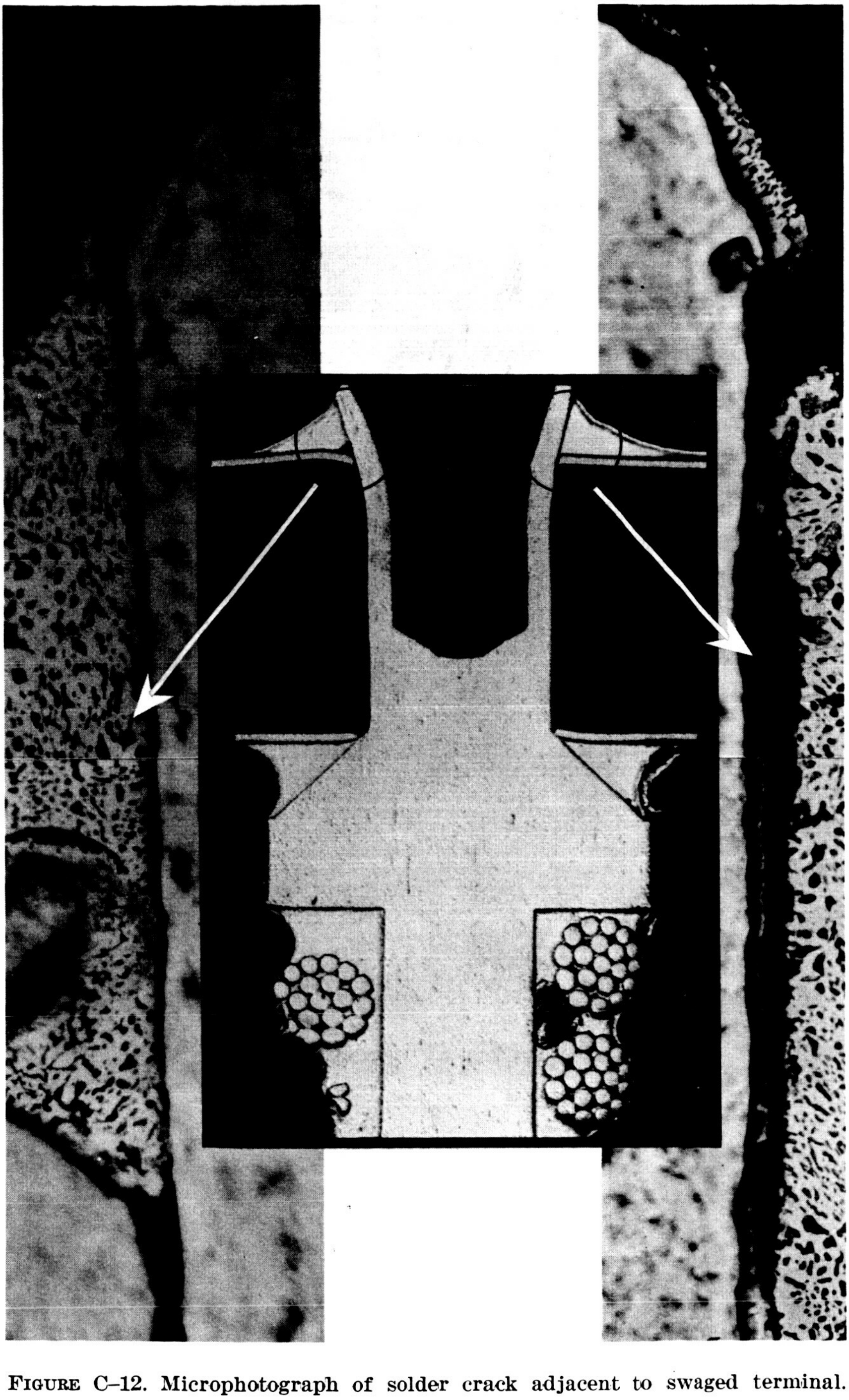

FIGURE C–12. Microphotograph of solder crack adjacent to swaged terminal.

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